

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY
FY2007.2 SBIR Proposal Submission

DARPA's charter is to help maintain U.S. technological superiority over, and to prevent technological surprise by, its potential adversaries. Thus, the DARPA goal is to pursue as many highly imaginative and innovative research ideas and concepts with potential military and dual-use applicability as the budget and other factors will allow.

DARPA has identified technical topics to which small businesses may respond in the fiscal year (FY) 2007 SBIR solicitation (FY2007.2). Please note that these topics are UNCLASSIFIED and only UNCLASSIFIED proposals will be entertained. Although they are unclassified, the subject matter may be considered to be a "critical technology" and may be subject to ITAR restrictions. If you plan to employ NON-U.S. Citizens in the performance of a DARPA SBIR contract, please inform the Contracting Officer who is negotiating your contract. These are the only topics for which proposals will be accepted at this time. A list of the topics currently eligible for proposal submission is included followed by full topic descriptions. The topics originated from DARPA technical program managers.

ALL PROPOSAL SUBMISSIONS TO DARPA MUST BE SUBMITTED ELECTRONICALLY THRU WWW.DODSBIR.NET.

It is mandatory that the complete proposal submission -- DoD Proposal Cover Sheet, **ENTIRE** Technical Proposal with any appendices, Cost Proposal, and the Company Commercialization Report -- be submitted electronically through the DoD SBIR website at <http://www.dodsbir.net/submission>. Each of these documents is to be submitted separately through the website. Your complete proposal **must** be submitted via the submissions site on or before the **6:00am EST, 13 June 2007 deadline**. A checklist has been prepared to assist small business activities in responding to DARPA topics. If you have any questions or problems with electronic submission, contact the DoD SBIR Help Desk at 1-866-724-7457 (8am to 5pm EST).

Acceptable Format for On-Line Submission: All technical proposal files must be in Portable Document Format (PDF) for evaluation purposes. The Technical Proposal should include all graphics and attachments but should not include the Cover Sheet or Company Commercialization Report (as these items are completed separately). Cost Proposal information should be provided by completing the on-line Cost Proposal form. This itemized listing should be placed as the last page(s) of the Technical Proposal Upload. (Note: Only one file can be uploaded to the DoD Submission Site. Ensure that this single file includes your complete Technical Proposal and the additional cost proposal information.)

Technical Proposals should conform to the limitations on margins and number of pages specified in the front section of this DoD solicitation. Your Cover Sheet will only count as two pages, no matter how they print out after being converted. Most proposals will be printed out on black and white printers so make sure all graphics are distinguishable in black and white. It is strongly encouraged that you perform a virus check on each submission to avoid complications or delays in submitting your Technical Proposal. To verify that your proposal has been received, click on the "Check Upload" icon to view your proposal. Typically, your proposal will be uploaded within the hour. However, if your proposal does not appear after an hour, please contact the DoD Help Desk.

DARPA recommends that you complete your submission early, as computer traffic gets heavy near the solicitation closing and slows down the system. DARPA will not be responsible for proposals being denied due to servers being "down" or inaccessible. Please assure that your e-mail address listed in your proposal is current and accurate. By the end of March, you will receive an e-mail acknowledging receipt of your proposal.

PLEASE DO NOT ENCRYPT OR PASSWORD PROTECT TECHNICAL PROPOSAL

HELPFUL HINTS:

1. Consider the file size of the technical proposal to allow sufficient time for uploading.
2. Perform a virus check.
3. Signature is no longer required at the time of submission.
4. Submit a new/updated Company Commercialization Report.
5. Please call the Toll Free SBIR Help Desk if you have submission problems: 866-724-7457

6. DARPA will not accept proposal submissions by electronic facsimile (fax) or email.

Additional DARPA requirements:

- DARPA Phase I awards will be Firm Fixed Price contracts.
- **If you collaborate with a University, please highlight the research that they are doing and verify that the work is FUNDAMENTAL RESEARCH.**
- Phase I proposals **shall not exceed \$99,000.** and may range from 6 to 8 months in duration. Phase I contracts cannot be extended.
- DARPA Phase II proposals must be invited by the respective Phase I DARPA Program Manager. Phase 2 invitations will be based on the technical results reflected in the Phase I contract and/or final reports as evaluated by the DARPA Program Manager utilizing the criteria in Section 4.3. DARPA Phase II proposals must be structured as follows: the first 10-12 months (base effort) should be approximately \$375,000; the second 10-12 months of incremental funding should also be approximately \$375,000. The entire Phase II effort should generally not exceed \$750,000.

Prior to receiving a contract award, the small business **MUST** be registered in the Centralized Contractor Registration (CCR) Program. You may obtain registration information by calling 1-888-227-2423 or Internet: <http://www.ccr.gov>.

The responsibility for implementing DARPA's Small Business Innovation Research (SBIR) Program rests with the Contracts Management Office. The DARPA SBIR/STTR Program Manager is Connie Jacobs, see address below. DARPA invites small businesses to submit proposals thru the DoD website www.dodsbir.net/submission.

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

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SBIR proposals submitted to DARPA will be processed by DARPA and distributed to the appropriate technical office for evaluation and action.

DARPA selects proposals for funding based on technical merit and the evaluation criteria contained in this solicitation document. DARPA gives evaluation criterion a., "The soundness, technical merit, and innovation of the proposed approach and its incremental progress toward topic or subtopic solution" (refer to section 4.2 Evaluation Criteria - Phase I - page 12), twice the weight of the other two evaluation criteria. PLEASE NOTE THAT MANY OF THE WEAKEST PROPOSALS SCORED LOW ON EVALUATION CRITERIA "C" "THE POTENTIAL FOR COMMERCIAL (GOVERNMENT OR PRIVATE SECTOR) APPLICATION AND THE BENEFITS EXPECTED TO ACCRUE FROM THIS COMMERCIALIZATION. DARPA IS PARTICULARLY INTERESTED IN THE POTENTIAL TRANSITION OF SBIR RESULTS TO THE U.S. MILITARY, AND EXPECTS EXPLICIT TREATMENT OF A TRANSITION VISION IN THE COMMERCIALIZATION-STRATEGY PART OF THE PROPOSAL. THAT VISION SHOULD INCLUDE IDENTIFICATION OF THE PROBLEM OR NEED IN THE DEPARTMENT OF DEFENSE THAT THE SBIR RESULTS WOULD ADDRESS, A DESCRIPTION OF HOW WIDE-SPREAD AND SIGNIFICANT THE PROBLEM OR NEED IS, AND IDENTIFICATION OF THE POTENTIAL END-USERS (ARMY, NAVY, AF, SOCOM, ETC) WHO WOULD LIKELY USE THE RESULTS. THE SMALL BUSINESS MUST DEMONSTRATE UNDERSTANDING OF THE END USE OF THEIR EFFORT AND THE END USERS.

ALL SELECTION/NON-SELECTION LETTERS WILL BE SENT TO THE PERSON LISTED AS THE "CORPORATE OFFICIAL" ON THE PROPOSAL.

As funding is limited, DARPA reserves the right to select and fund only those proposals considered to be superior in overall technical quality and highly relevant to the DARPA mission. As a result, DARPA may fund more than one

proposal in a specific topic area if the technical quality of the proposal(s) is deemed superior, or it may not fund any proposals in a topic area. Each proposal submitted to DARPA must have a topic number and must be responsive to only one topic.

- Cost proposals will be considered to be binding for 180 days from closing date of solicitation.
- **Successful offerors will be expected to begin work no later than 30 days after contract award.**
- For planning purposes, the contract award process is normally completed with 45 to 60 days from issuance of the selection notification letter to Phase I offerors.

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DARPA SBIR 07.2 Topic Descriptions

SB072-001 TITLE: Nanotechnology-Enhanced Sensor for Toxic Industrial Chemicals

TECHNOLOGY AREAS: Air Platform, Chemical/Bio Defense, Ground/Sea Vehicles, Materials/Processes, Biomedical

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: Develop a lightweight, portable sensor for toxic industrial chemicals (TICS) that incorporates nanoscale features to enhance detection sensitivity while reducing reagent requirements.

DESCRIPTION: Toxic industrial chemicals (TICS) also referred to as toxic industrial materials (TIMS), are chemicals not classified as chemical warfare agents that are harmful or lethal to humans. Toxic industrial chemicals include well known substances such as ammonia, chlorine, and hydrogen fluoride which are considered to be highly toxic, to lesser known materials such as acrolein and chloroacetaldehyde. The threat from TICS, while not being as lethal as traditional chemical agents, is enhanced due to the vast quantities produced and the ease of access to the materials compared to chemical agents. Additionally, most chemical agent detectors are not configured to detect TICS, thus exposure may not be recognized until significant exposure has occurred. The use of the military in urban areas will likely increase the risk to the warfighter of exposure to TICS used as weapons either through direct exposure or through the introduction of the chemical into the food and/or water sources used by the troops. TICS also pose a risk to the general population due to the proximity of chemical manufacturing and usage facilities to population centers. The goal of this effort is to take advantage of advances in nanofabrication technologies to develop small sensors for TICS that incorporate nanoscale features along with microfluidics to increase sensitivity while reducing reagent and power requirements. Any proposed sensor should be able to detect a wide range of TICS and/or be easily reconfigurable in order to detect additional chemicals. Additionally, proposed sensors should be designed with the following considerations in mind: 1) low power consumption operation, 2) capability for remote operation, including wireless data transmission, and 3) ruggedized construction of small reconfigurable sensors for use in battlefield scenarios such as mounted on unmanned aerial vehicles (UAV's) and/or unmanned ground vehicles (UGV's). The proposed sensors should also have a low likelihood of false alarms.

In support of this effort, selective U.S. Army Aviation and Missile Research, Development, and Engineering Center (AMRDEC) fabrication and testing facilities are available for use by SBIR contractors AT NO CHARGE. Specific government furnished equipment (GFE) and restrictions are available upon request.

PHASE I: Conduct a feasibility study on the design and development of a sensor for toxic industrial chemicals the performance of which is enhanced by the incorporation of nanoscale features.

PHASE II: Develop and Demonstrate initial detection capabilities/methods for the toxic industrial chemicals having the highest hazard index as determined by the Department of Homeland Security. Experimentally test and validate the performance of the prototype system. Submit a working prototype to the Army for testing.

PHASE III DUAL USE APPLICATIONS: The sensors developed under this topic will have broad dual use applications outside of the military including homeland defense areas, environmental quality monitoring, and industrial chemical monitoring.

REFERENCES: 1) Guide for the Selection of Chemical Agent and Toxic Industrial Material Detection Equipment for Emergency First Responders, Department of Homeland Security Guide 100-04, Volume 1, March 2005
2) Optical detection of chemical warfare agents and toxic industrial chemicals: Simulation, M.E. Webber, M. Pushkarsky, C.K.N. Patel, Journal of Applied Physics, Volume 97, Issue 11, pp. 113101-11 (2005).

KEYWORDS: Chemical Detection, Environmental Monitoring, Toxic Industrial Chemicals, Toxic Industrial Materials

SB072-002 TITLE: Innovative Pulse Programmers for Quantum Computing Applications

TECHNOLOGY AREAS: Information Systems, Sensors, Electronics

OBJECTIVE: Research and development of innovative techniques and architecture for precise control and generation of complex pulse shape and sequence to enable qubit operations for scalable quantum computing.

DESCRIPTION: Logic operations and error correction in trapped ion, superconducting, and semiconductor qubits are performed by sequences of shaped pulses that modulate voltages applied to control electrodes or gates. This topic seeks scalable generator of precisely shaped pulse sequences through the design and development of innovative techniques, a reconfigurable and extensible architecture, and five modular subsystems of programmable hardware.[1] The first module is a high-speed Digital Sequencer to produce sequenced digital control outputs under software control. Second is a RF Subsystem (typically 400 MHz) interfaced to the Digital Sequencer to synthesize RF output with digitally controlled amplitude, phase, and frequency. Third is a high-speed Digital Serializer, interfaced to the Digital Sequencer, to output serial streams of digital bits with buffered TTL, LVTTTL, ECL, or LVDS output. High-speed operation and radiated energy (noise source) would be important considerations in the choice of the output type. Fourth is a High Frequency radio frequency (RF) Subsystem that interfaces the Digital Sequencer to high-speed 16-bit D/A converters and provides buffered 50 ohm outputs. Fifth is a Waveform Synthesizer interfaced through D/A converters to the Digital Sequencer and provides outputs, typically to 50 ohms.

PHASE I: The Phase I study should describe the design and estimate performance of a prototype programmable pulse sequence generator based on commercial off the shelf (COTS) components that can perform scalable qubit operations. Prototype hardware design should include a memory depth of at least 4 MB by 18 or 2 MB by 36 for the Digital Sequencer. A performance reference for RF synthesis for the 400 MHz RF Subsystem is the Analog Devices AD9858 chip. The Digital Serializer should output at least 4 serial streams of digital bits at 16 times the speed of the Digital Sequencer (or 8 by 8) using parallel-to-serial conversion chips. The High Frequency RF Subsystem should interface the Digital Sequencer to 4 high-speed 16-bit D/A converters, such as the 500 MSPS Maxim MAX5898 chip, and provide buffered 50 ohm outputs. The Waveform Synthesizer should interface sixteen 20-MHz 16-bit D/A converters to the Digital Sequencer and provide 50 ohm low voltage outputs (examples; 0-3V, +-3V, +-5V, or +- 10V).

PHASE II: Construct a prototype generator of precisely shaped pulse sequences in an extensible architecture able to control 100 qubits using open source hardware and software. Adaptability of the plug and play design to meet the requirements of different qubit embodiments, and addressability of hot-swappable modular units in subsystems, must be demonstrated using low noise, low jitter hardware. The prototype must interface with high-level programming software to control qubit operations. Requirements and testing should be done in coordination with an experimental group developing appropriate qubits.

PHASE III DUAL USE APPLICATIONS: The technology developed here has application to a broad range of quantum computing technologies. In addition to critical national security applications, quantum computing is anticipated to have an impact on commercial applications involving hard computational problems such as planning and scheduling. The technology developed here is also anticipated to have wide application to DoD and commercial applications involving pulse generators, pulse shaping, and pulse sequencing.

REFERENCES: 1) <http://pulse-sequencer.sourceforge.net/>
<http://www.darpa.mil/SBIR/workshopresults/pulseprogrammer>
2) Kenneth R. Brown, Aram W. Harrow, Isaac L. Chuang: Phys. Rev. A v70, p052318, Nov. 2004.
3) H. Haffner et al.: Appl. Phys. B 81, p. 151 (2005).
4) R. McDermott et al.: Science 307, pp. 1299-1302 (2005).
5) J.R. Petta et al.: Science 309, p. 2180 (2005).

KEYWORDS: Pulse Generators, Pulse Shaping, Pulse Sequence, Quantum Computing.

SB072-003 TITLE: Crack Nucleation Prediction through Surface Roughness Measurement

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Identify and develop innovative methodologies to predict crack nucleation in aircraft grade Al alloys as a function of the surface roughness.

DESCRIPTION: Much success has been realized predicting the remaining useful life of critical airframe parts through the analysis of downloaded flight data under the DARPA Prognosis Program. The development of an analytical technique to measure surface and predict the nucleation of fatigue cracks based on this measurement would further enhance the capabilities previously developed under Prognosis. The ability to predict crack nucleation based on surface roughness measurements would further reduce the need to have frequent inspections that require an airframe to be out of service and incur significant costs. Previous studies have shown a large effect of roughness on crack nucleation conditions [1, 2]. In order to achieve this, variable surface quality must be quantified and correlated to the fraction of contribution to the system that causes a crack to nucleate under fatigue loading.

PHASE I: Conduct a study on fatigue crack growth as a function of surface roughness. Conditions would be similar to loading profiles as those established in Prognosis. Develop portable, easy-to-use, non-contact profilometry measuring techniques to be used for inspections.

PHASE II: Develop a set of algorithms for predicting fatigue crack initiation based on physics and data-driven models gathered in Phase I. Produce predictive computer code/module with easy integration into existing commercial software package FASTRAN code developed under Prognosis.

PHASE III DUAL USE APPLICATIONS: The technology developed under this SBIR can be used in military and civilian inspection schemes such as Navy aircraft EA-6B, P-3, and Air Force aircraft A10 and for commercial civilian legacy airframe applications.

REFERENCES: 1) Proudhon, H., Fouvry, S., and Buffiere, J.-Y., "A fretting crack initiation prediction taking into account the surface roughness and the crack nucleation process volume," Int. J. Fatigue, 27 (5), 2005, 569-579.
2) Lovrich, N. R. and Neu, R. W., "Effect of mean stress on fretting fatigue of Ti-6Al-4V on Ti-6Al-4V," Fatigue & Fracture of Engineering Materials and Structures, 29 (1), 2006, 41-55.

KEYWORDS: Fatigue Cracking, Surface Profilometry, Modeling, Al Alloys

SB072-004 TITLE: Synthetic Combinatory Bendable Substrates (CyCoBs) for Ultra-lightweight, Structurally Embedded Infrared (IR) Camera

TECHNOLOGY AREAS: Materials/Processes, Sensors

OBJECTIVE: Identify and develop innovative technologies to enable ultra-lightweight IR cameras for use on Micro Air Vehicles (MAVs) to achieve long endurance (> 90 mW-hr) and carry high power payloads.

DESCRIPTION: Currently available small infrared (IR) and short wavelength infrared (SWIR) cameras are ~100 grams in weight. DARPA aims to develop cameras with equivalent performance at less than 1/10th the mass. A large portion of the mass of a state-of-the-art camera is dedicated to the focal plane array (FPA), read out circuitry, cooling system, lens assembly, signal processing, and energy storage. There is immediate need to address these limitations to achieve a small IR camera that weighs less than 10 grams and possesses state-of-the-art sensitivity that can be integrated directly on Micro Air Vehicle platforms (e.g., DARPA's Wasp MAV). Weight savings will be achieved through the exploitation of the multifunctional materials concept. For example, by imprinting the structural MAV components with Focal Plane Array (FPA) and readout circuitry to provide more efficient

packaging, thermal management, incorporation of novel lens assemblies and communication antennas into the airframe it may be possible to achieve reduced weight, and, therefore, increased endurance [1-3].

PHASE I: Conduct a feasibility study on transferring FPA circuits from rigid to flex substrates using die level elements on plastic with more efficient packaging, improved cooling, and incorporation of novel lens assemblies. Reducing package weight and thinning substrates will result in a reduction in weight from 25-50 g (state-of-the-art) to <1 g.

PHASE II: Develop the materials and methods identified in Phase I and integrate solutions with MAV structural elements. Produce functional lightweight IR with FPA on flex chip integrated to MAV structure with 1/10th the current mass.

PHASE III DUAL USE APPLICATIONS: The technology developed under this SBIR can be used in military and civilian IR cameras such as on-board WASP and for civilian inspection applications.

REFERENCES: 1) Y. Xiao, H. N. Shah, R. Natarajan, E. J. Rymaszewski, T. P. Chow, R. J. Gutmann, "Integrated flip-chip flex-circuit packaging for power electronics applications," IEEE Transactions on Power Electronics, 19 (2), 2004, 515-522.

2) Rivera, A. and Murray V., "Friendly Eyes, Hostile Skies: An SwRI-developed flight management system adds capability to compact unmanned aircraft system", SwRI Technology Today, 27 (2), 2006, 8-11.

3) Paradiso, J. A. and Starner T., Energy Scavenging for Mobile and Wireless Electronics, IEEE Pervasive Computing, 4(1), 2005, 18-27.

4) <http://www.darpa.mil/dso/thrust/matdev/wasp.htm> DARPA WASP program

KEYWORDS: Cameras, Sensor Array, Flexible Substrate, Material Processing.

SB072-005 TITLE: Spatial Control of Crystal Texture

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop a manufacturing process for spatial control of crystal texture in metallic components and demonstrate an application where performance is enhanced due to the control of the texture.

DESCRIPTION: Solid Freeform Fabrication (SFF) is a class of layered manufacturing processes which convert computer representations of components into solid components without part specific tooling. Examples of SFF include Stereolithography, 3-D Printing, Fused Deposition and Laminate Object Manufacturing. Many of these processes have been used to manufacture metal component via powder metallurgy. In powder metallurgy large seed grains may be oriented in the 'green state' to control crystal texture via secondary grain growth. Since tensor properties of material depend on crystal orientation, it would be useful to control properties spatially within a component to enhance the performance of components. Development of machine capabilities for the spatial control of crystal texture (for each voxel or volume element) provides a method of making things that can't be manufactured by conventional manufacturing methods.

Each proposal must include a Defense relevant challenge problem for manufacture where the spatial control of crystal texture is essential to the enhanced performance. A few examples are given of suitable challenge problems although the proposer may choose any Defense relevant problem.

1. Depleted Uranium (DU) is used as a ballistic penetrator in part because of its self sharpening behavior. Proper orientation of shear planes in another material without self sharpening behavior could be used to change its failure behavior to enhance penetration.

2. Single crystal turbine blades have superior creep rupture properties compared to polycrystalline turbine blades but the manufacturing process is slow and therefore expensive. Proper orientation of seed grains might be used to self assemble single crystal turbine blades complete with internal cooling passages.

3. Magnetic pole pieces can be designed such that magnetic field strength is enhanced by orienting the crystallographic axis with the highest permeability to follow the field lines in the magnet. Currently such magnets

are produced by cutting pieces from a textured billet and assembling and bonding a mosaic of magnetic pieces. Such magnets could be made directly with the machine capabilities to be developed in this project.

PHASE I: Establish sintering conditions and seed grain requirements for secondary grain growth for the alloy composition of interest. Develop and demonstrate a laboratory scale manufacturing process for spatial control of crystal texture suitable for the chosen challenge problem. Develop models to describe how spatial control of crystallographic texture affects the performance of the demonstration component.

PHASE II: Based on the results of Phase I, design and build a second generation computer driven machine capable of manufacturing components for test and evaluation. Characterize the performance of the components of manufacture and how the performance changes with changes in the design for spatial control of texture.

PHASE III DUAL USE APPLICATIONS: The manufacturing process developed in this project may also be used to control the tensor properties of materials. This could for example be used to increase the surface hardness of armor systems. When applied to ceramic materials, the machine capability developed in this program could be used to enhance optical or piezoelectric performance.

REFERENCES: 1) DU Exposure in the Gulf war: http://www.gulflink.osd.mil/du_ii/du_ii_tabg.htm

2) P. W. Rehrig, S-E. Park, S. Trolier-McKinstry, G. L. Messing, B. Jones, and T. R. ShROUT, "Piezoelectric Properties of Zirconium-doped Barium Titanate Single Crystals Grown by Templated Grain Growth," J. Appl. Phys. 86(3):1657-1661 (1999).

3) "Fabrication of Grain Oriented Lead Metaniobate Components by fused deposition of Ceramics", K. Nonaka, M. Allahverdi, A. Safari, J. of Ferroelectrics, Vol. 269, pp. 255-260, 2002.

KEYWORDS: Solid Freeform Fabrication, Penetrator, Turbine Blade, Magnetic Pole Piece, Crystal Texture, Manufacturing.

SB072-006 TITLE: Advanced Development for Defense Science and Technology

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Identify and develop innovative technology in the Physical, Engineering, and Life Sciences for enabling defense technology.

DESCRIPTION: Novel technology which relies on innovations in science and engineering has provided a critical advantage to our national defense. To this end, DSO is soliciting proposals for advanced technology development in a variety of enabling technical areas which include:

- Application and development of advanced mathematics for DoD applications.
- New and innovative approaches to biosensor technology and biological technology for maintaining the warfighters performance, capabilities and survival in battlefield conditions.
- Remote interrogation and control of biological systems at the system/organ/tissue/cellular/molecular scales and new technologies to drastically reduce the logistics burden of medical treatment in the field;
- Novel interface and sensor designs for interacting with the central (cortical and subcortical structures) and peripheral nervous systems, with a particular emphasis on non-invasive and/or non-contact approaches;
- New technologies for understanding and predicting the behavior of individuals and groups, especially those that elucidate the neurobiological basis of behavior and decision making;
- New technology for training individuals and teams, including embedded training and simulation; technologies which lead to understanding and improving team performance; and new approaches to improve rapid decision-making in chaotic or data-poor environments.

PHASE I: Conduct a feasibility study which would investigate and define the proposed idea or device and its feasibility.

PHASE II: Develop the research and technology advances and methods identified in Phase I to demonstrate a proof-of-concept prototype.

PHASE III DUAL USE APPLICATIONS: The technology developed under this SBIR will be used in military and civilian commercial sector.

REFERENCES: 1) <http://www.dod.mil/ddre/mainpage.htm>
2) <http://www.dod.mil/ddre/scitech.htm>
3) <http://ostp.gov/html/m06-17.pdf>

KEYWORDS: Sensor Array, Biotechnology, Novel Materials, Embedded Training, Decision Making, Neural Signal Analysis

SB072-007 TITLE: Tracked Vehicle Barriers

TECHNOLOGY AREAS: Materials/Processes, Battlespace

OBJECTIVE: Identify and develop innovative portable barriers to restrict tracked vehicle movement in a wide variety of tactical situations.

DESCRIPTION: Current barrier systems used to impede enemy freedom of movement are labor and logistics intensive, requiring significant time, manpower, equipment, and materials to emplace and sustain. This problem is exacerbated for the larger-scale (e.g., Jersey) barriers used to deny larger tracked vehicles such as tanks. There is an immediate need for lightweight small-volume barrier systems which can stop or degrade the forward motion of tracked vehicles. Such systems are envisioned to have a small form-factor when stored, but upon deployment will expand to achieve the desired operational form-factor. Furthermore, it is desired for the barriers to be fully reversible and reusable. Barriers for wheeled vehicles such as trucks and sedans, constructed from polymeric foams and other lighter weight components, are currently under development. This topic addresses the more difficult problem of stopping a heavy tracked vehicle such as an M1A2 tank (70 tons), an SP Howitzer (40 tons), or a Bradley (50 tons). Innovative approaches, such as designs which use the mass and momentum of the vehicle itself as part of the stopping mechanism, or which incorporate mimics of terrain conditions known to impede tracked vehicle movement (soft ground, mud, water, or significant slope) are sought.

PHASE I: Design and test concept for an expandable lightweight (<10 lb) barrier capable of stopping a tracked vehicle. The barrier will be reversible and reusable. Barrier must be deployed and reversed in under 5 min.

PHASE II: Develop manufacturable prototype barriers and demonstrate performance in field tests.

PHASE III DUAL USE APPLICATIONS: The technology developed under this SBIR can be used in military operations, law enforcement, and industrial safety.

REFERENCES: 1) Jane's Military Vehicles and Logistics, 26th Edition (2005), Jane's Information Group.
2) Military Field Manual FM 5-114, "Engineer Operations Short of War."

KEYWORDS: Barrier, Tracked Vehicle, Lightweight, Reversible, Reusable, Expandable, Rapid Deployment

SB072-008 TITLE: Novel Architectures Development

TECHNOLOGY AREAS: Information Systems, Sensors, Electronics, Weapons

OBJECTIVE: This SBIR solicits novel, unique, breakthrough processing approaches and architectures (including novel micro-architectures, input/output (I/O), and related technologies) for tomorrow's embedded and mainframe DoD applications. The goal is to identify and pursue leap-ahead processing architecture techniques and approaches

that will provide revolutionary new processing and productivity capabilities. In summary, this SBIR seeks fresh new promising ideas required to seed future new directions in processing for DoD and commercial applications.

DESCRIPTION: Military platforms and systems for many applications require real-time, high-performance computing, but typically have severe constraints on space, weight, power, latency, and cost. Computing solutions are increasingly being implemented with commodity processing systems, which, because they are driven by mass-market demands and need to accommodate generations of legacy code, cannot provide revolutionary innovations in both hardware and software. More importantly, the gap between critical high-end DoD processing needs and the incremental progress of commercial industry is continuing to widen and threaten US superiority in an area that is a foundation of our national security.

This SBIR pursues concepts outside mainstream commodity design developments. It is imperative that proposers describe and justify how their processing architectures and/or concepts far surpass today's evolutionary processors, in both performance and productivity. Novel, break-through processing architectures and approaches are sought that are especially relevant to DoD applications and that can dramatically drive processing capabilities forward to both dramatically enhance today's applications and enable a whole new spectrum of DoD applications. This SBIR seeks to initiate a new generation of computer concepts and architectures that are both truly innovative in concept and approach, are currently unexplored by today's mainstream commodity developers, and provide significant, quantifiable advances in performance and productivity for a broad user community.

PHASE I: Identify and evaluate leap-ahead processing architectures. Establish novel and revolutionary processing approaches, architectures, and technologies that will provide leap-ahead processing performance and productivity. Conduct feasibility studies on the proposed architectures, detail the architectural approaches proposed, establish the productivity and performance advantages and advancements, and propose plans to proceed to full development of the proposed revolutionary architectures.

PHASE II: Develop selected leap-ahead, revolutionary processing approaches, architectures, and technologies from Phase I. Establish the viability of these architectures, both for DoD and commercial applications. Fully develop the proposed architectures and critical design elements. Initiate the path to full-scale development and fabrication approaches for the identified architectures. Develop test structures and demonstration devices to verify critical elements of the architectures. Identify technology transition pathways to DoD applications and platforms – initiate transition and insertion opportunities based on the novel architectures' processing performance and productivity advances.

PHASE III DUAL USE APPLICATIONS: Develop DoD transitions and insertions to utilize the processing breakthroughs. Also, pursue technology transitions and insertions into commercial processing architectures. The selected novel architectures will enable a new spectrum of DoD and commercial applications. Commercial applications include a range of functions, from real-time 3-D medical imaging to personal computers that adapt to and anticipate their users' needs.

REFERENCES: 1) "Clock Rate Versus IPC: The End of the Road for Conventional Microarchitectures," V. Agarwal, M.S. Hrishikesh, S.W. Keckler, and D. Burger (University of Texas at Austin), 27th International Symposium on Computer Architecture (ISCA), June, 2000, <http://www.cs.utexas.edu/users/cart/trips/publications/isca00.pdf>
2) "Stream Programming: Managing Explicit Parallelism and Locality," Bill Dally (Stanford University), EDGE workshop briefing – EDGE Workshop University of North Carolina at Chapel Hill, 24 May 2006, <http://gamma.cs.unc.edu/EDGE/SLIDES/dally.pdf>

KEYWORDS: Unique Micro-Architectures, Novel Processing Architectures, Revolutionary Architectures, High Performance, Productivity, Fabrication.

SB072-009 **TITLE:** Self Aware Processing

TECHNOLOGY AREAS: Information Systems, Sensors, Electronics, Weapons

OBJECTIVE: Apply cognitive and other appropriate approaches to monitor, assess, and control system resources for optimized productivity – performance and use of resources – for dynamic mission and system conditions.

DESCRIPTION: Current high-performance processing systems are complex and frequently composed of heterogeneous processor subsystems. These systems are typically static in nature, and predetermined prior to deployment. If mission dynamics or system performance change, these systems are limited to their originally predetermined mode of operation, resulting in inefficient use of resources and performance penalties at best and catastrophic failure at worst. An example of a potentially inefficient use of resources and system limitations could be illustrated for multi-tasking systems. Efficient pre-set, static utilization of system resources for multiple tasks will be difficult to establish given dynamic mission requirements. Priorities would be fixed and resources explicitly set given pre-mission expectation. These priorities could easily change a mission due to dynamic situations, altered missions, or actual hardware failures. A hardware failure could lead to loss of a high priority activity and loss of a mission despite the availability of other resources capable of performing the mission. A self-aware system could balance resources, efficiencies, and mission priorities to efficiently use system resources to dynamically and effectively meet mission requirements. This SBIR addresses these limitations by pursuing the development of self-aware processing systems that monitor their own condition and state, evaluate that condition and available resources, and respond by re-allocating resources to manage and optimize system performance.

The SBIR seeks approaches and techniques that will observe and monitor system performance, i.e., detect system failures, monitor usage of system resources, and observe overall system performance and then manage and utilize system resources for maximized overall mission performance. Maximized performance of systems is anticipated to be enhanced by the application of cognitive and self-aware approaches to monitoring and managing usage of system resources. Such technologies could detect and correct system anomalies and failures, and optimize system resource configuration. Proposers are encouraged to examine and incorporate the use of cognitive approaches to address all of the areas described above with a single end-to-end solution, but may also consider novel approaches that address one or more of the individual areas described above.

PHASE I: Develop and evaluate concepts and approaches for self-aware processing systems. Proposals should include techniques for monitoring processor state, system capability, and performance; techniques for managing and configuring system resources to achieve best performance; and quantitative, systematic methodologies for measuring and evaluating the efficacy of these techniques. This SBIR topic encourages, but is not limited to, cognitive approaches. Plans to develop and implement the proposed concepts and approaches should be included in the Phase I proposal.

PHASE II: The most promising concepts and approaches from Phase I will be fully developed in Phase II. Demonstrations of key concepts and implementations on variable size systems will be developed to verify the proposed approaches. The impact on selected, critical DoD applications will be evaluated, and transitions to DoD platforms and applications will be initiated.

PHASE III DUAL USE APPLICATIONS: The implementation of self-aware techniques and capabilities would enable self-optimizing and fault/failure resistant systems for applications ranging from critical DoD missions to real-time complex medical imaging and diagnostic systems to personal computers; it would increase the reliability and reduce the maintenance for systems, ranging from large-scale production facilities to multi-application office applications. Self-aware systems will provide major advances in reliability, performance and productivity for both DoD and industry.

REFERENCES: 1) “Organic Computing,” Anant Agarwal (MIT CSAIL) and William Harrod (DARPA IPTO), Self Aware Computing Concepts Paper, 3 August 2006, <http://www.cag.csail.mit.edu/raw/documents/Agarwal-Harrod-organic-2006.pdf>

KEYWORDS: Self-Aware, Reliable Processing, Adaptive Processing, System Optimization, Reactive Systems, Self-Optimizing Processing; Self-Managing Systems.

TECHNOLOGY AREAS: Information Systems, Sensors, Electronics, Weapons

OBJECTIVE: Develop innovative, unexplored approaches for addressing and utilizing homogeneous and heterogeneous multi-core processors. Key areas of interest include, but are not limited to, novel operating systems, new language extensions, comprehensive software environments, and tools that address multi-core resources and make application development transparent to the user.

DESCRIPTION: The advancement of on-chip processing performance has moved from increases in clock speed to the use of parallel processing resources that utilize the increasing number of transistors available on current and future chips. This change requires a fundamental change in the way applications are developed and implemented. DoD application developers now face a far more complex problem: the efficient use of multiple cores on a single microprocessor. This problem has been a historic and continuing major issue for large scale, massively parallel, high performance systems. However, as chips have become increasingly complex and multi-tiled (multi-cored), the problem of developing applications for parallel processing systems now extends to single chip processing resources. The ability to efficiently address and utilize parallel processing resources will be a key to optimizing efficient use of large multi-core processors, both for high-end and embedded systems.

This SBIR seeks novel, innovative techniques and approaches to deal with the problems associated with the efficient and effective use of multi-core processors. As the leading industrial processor developers move from dual and quad core processors to 10 and 100s of processing cores on a chip, application developers will increasingly need effective techniques to utilize these resources. This topic addresses these issues by soliciting a novel suite of software aimed specifically at solving the unique problems facing users of multi-core processors. Software of interest includes, but is not limited to: automated or semi-automated application mapping tools, new operating systems, new language extensions, new debugging and other tools, and transparent application development environments that make multi-core systems accessible to an increasingly wider user community. Proposed technologies should demonstrate their ability to scale as multi-core processors increase in number of cores. Proposed techniques and approaches should address both the processing device and system level. Proposers are encouraged to address approaches that will dramatically improve current DoD missions and enable ambitious new DoD applications.

PHASE I: Identify, establish, and evaluate approaches and techniques to effectively utilize multi-core processors, both homogeneous and heterogeneous. Conduct feasibility studies of the proposed approaches, provide a detailed technical approach, provide quantitative measures of the productivity and performance advantages and advancements, establish and justify the viability of the proposed approaches, and propose plans to proceed to full development of the proposed techniques and approaches.

PHASE II: Develop the selected multi-core software techniques and approaches from the Phase I designs. Demonstrate the effectiveness of the techniques using existing multi-core processors. Initiate developments that will provide the developing capabilities to DoD and commercial user communities. Initiate transition and insertion opportunities based on the developing performance and productivity advances.

PHASE III DUAL USE APPLICATIONS: High-performance processing is critical to DoD and commercial applications. The efficient and effective use of processing resources, both current and future – as represented by the commercial development of multi-core processing systems as the path for future processing architectures as identified by leading processing device developers – will be critical to enabling any high performance processing application.

REFERENCES: 1) Sutter, Herb. « The Free Lunch is Over : A fundamental Turn Towards Concurrency in Softwear ». Dr. Dobbs Journal, Volume 30, Number 3. March 2005.

<http://www.gotw.ca/publications/concurrency-ddj.htm>

2) Halfhill, T « Multi-Cor Programming .» September 19, 2005

http://maximumpc.com/2005/09/multi-core_prog.html

3) A. Agarwal (MIT) “The Why, How and When of Multicore”, EDGE workshop briefing – EDGE Workshop University of North Carolina at Chapel Hill, 23 May 2006, <http://gamma.cs.unc.edu/EDGE/SLIDES/agarwal.pdf>

KEYWORDS: Multi-Core Processor Software, Multi-Core Processor Operating Systems, Multi-Core Processor Languages, Multi-Core Processor Tools, Multi-Core Processor Development Environments, Heterogeneous Systems, Application Implementation Efficiency, Sustained Performance, Processor Utilization.

SB072-011 **TITLE:** Cognitive Assistance Tools for Victims of Traumatic Brain Injury

TECHNOLOGY AREAS: Information Systems, Human Systems

OBJECTIVE: Develop a range of “cognitive prosthetic” systems to enhance the day-to-day effectiveness, independence, control and quality-of-life of soldiers and veterans with traumatic brain injury.

DESCRIPTION: Traumatic Brain Injury (TBI) occurs among OIF/OEF (Operation Iraqi Freedom/Operation Enduring Freedom) wounded, due in large part to blast damage caused by IEDs (Improvised Explosive Devices). In terms of war-related injuries, TBI is more frequent than amputation. Additionally, over one million civilians are treated for TBI in the United States every year; 5.3 million Americans are living with a TBI-related disability; and 17.9 million Americans have cognitive disabilities. Often, diagnosis may be complicated because of an interaction between TBI and Post Traumatic Stress Disorder. Even moderate TBI can cause personality changes, as well as serious problems with memory, attention, decision-making, self-awareness, and self-control.

Our objective is to develop systems that enhance day-to-day control and effectiveness of people with TBI, providing compensatory functions where needed. These tools may combine a portable computing system with miniature sensors (e.g. small video camera, microphones, GPS) and cognitive software techniques that can make appropriate inferences. Based on the situation, state of the user and the user history, a user will be cued with appropriate information to assist with his actions or decisions in an optimal manner. A range of rehabilitation or restorative techniques to train brain-injured people to improve their ability to interact with real-time, real-world life situations may also be developed. This topic does not address research whose principal purpose is to further our understanding of brain function, but the systems envisioned might also collect data useful to researchers.

This effort is enabled by continuing rapid progress in two technology areas. The first is the continued miniaturization of sensing and computing devices such as video cameras, audio recorders, global position systems (GPS) and inertial navigation devices, and computing platforms like personal digital assistants (PDAs). The second is the emergence of computer cognitive techniques for storing, indexing, and retrieving data from these sensors and techniques for interpreting sensor data, inferring additional information about the world, and modeling intentions and internal state.

The systems envisioned by this topic span a broad spectrum of possible capabilities and realizations. The system may emphasize to varying degrees the prosthetic augmentation of patient capability, patient rehabilitation, relieving the burden on caregivers, real-time behavioral assessment, or long term measurement of progress. It may interact solely or principally with the patient, or with family, immediate caregivers, therapists, doctors, or researchers. Its realization may involve many different possible components, including different types of hardware (e.g., worn sensors, PDAs, laptops), software (e.g., cognitive software, knowledge bases), and other system-level elements (e.g., internet and other connectivity, database resources, web-based services). Proposers should be specific about what their proposed system is intended to do (and for whom), and what resources will be utilized in its implementation.

PHASE I: Develop a detailed system concept and initial design for a cognitive prosthetic system, and create a preliminary demonstration relevant to the proposed system. In addition to hardware components, identify and characterize the cognitive sensory interpretation and modeling capabilities required to fully implement the system, and define the approach to be used to develop them. Identify thresholds of subsystem capability that translate into thresholds of system-level capability, and define performance metrics for the system.

PHASE II: Refine and expand the system concept developed under Phase I. Develop a complete demonstration system and demonstrate performance in scenarios relevant to challenges experienced by patients suffering from moderate TBI.

PHASE III DUAL USE APPLICATIONS: This technology can be commercialized by industry for use with civilian brain injuries, as well as military/veteran needs.

REFERENCES: 1) Defense and Veterans Brain Injury Center website, <http://www.dvbic.org/>
2) E.F. LoPresti, A. Mihailidis, N Kirsch, "Assistive technology for cognitive rehabilitation: state of the art", *Neuropsychological Rehabilitation*, 2004, 14(1/2), pp 5-39.
3) K.D. Cicerone, C. Dahlberg, J.F. Malec et al, "Evidence-Based Cognitive Rehabilitation: Updated Review of the Literature from 1988 Through 2002", *Arch Phys Med Rehabil* Vol 86, Aug 2005, pp 1681-1691.
4) W. Garmoe, A.C. Newman, M. O'Connell, "Early Self-awareness Following Traumatic Brain Injury", *J Head Trauma Rehabil*, Vol 20, No 4, Jul-Aug 2005, pp 348-358.
5) M. E. Pollack, L. Brown, D. Colbry, C. E. McCarthy, C. Orosz, B. Peintner, S. Ramakrishnan, and I. Tsamardinos, "Autominder: An Intelligent Cognitive Orthotic System for People with Memory Impairment," *Robotics and Autonomous Systems*, 44(3-4):273-282, 2003.

KEYWORDS: Cognitive, Brain Injury, Prosthetic, Brain Mapping

SB072-012 TITLE: Game World

TECHNOLOGY AREAS: Information Systems, Human Systems

OBJECTIVE: Develop a framework that permits game development by non programmers and the cooperative assessment of a range of instructionally rich educational games using performance on other games as the learning metric.

DESCRIPTION: This topic seeks to address a military training problem as well as the current science and technology education crisis. Simulators used for military training have become increasingly realistic due to technological advancements. However, there is variability in the efficacy of these simulators due in large part to the degree to which they captivate and engage users. Furthermore, it isn't clear how to distinguish those that are more effective from those that are less effective. In terms of education, waning interest in the pursuit of science and technology is weakening the U.S. in the face of growing international competition. Having the ability to generate entertaining video games that teach effectively would address both of these problems and serve a broad range of related interests as well. It is expected that the successful application of science and technology curricula to the video-gaming medium would result in tremendous gains in both learning quantity and efficacy by exploiting the significant time allocation and high content retention associated with the video-gaming medium. Furthermore, it is expected that the successful application of video-gaming to military training curricula would reduce training and improve field performance due to the rapid skill acquisition and other benefits associated with intrinsically-motivated learning (see Deci & Ryan). A system built upon gaming frameworks and novel analytic approaches could be developed to provide learning metrics that could be derived from undirected game play. Such a system could identify highly-effective instructional video games through an innovative statistical analysis of the high-volume game play data expected to accompany a high entertainment quotient. Of particular interest are approaches that encourage game submissions and permit games to compete for learning efficacy. One way to do this would be to develop or adapt a gaming framework (e.g., 3D Gamemaker, StageCast, etc.) that allows both programmers and non-programmers to develop gaming content. The games could be made available for public use and performance incentives (e.g., prizes for high scores) could be offered to promote participation. The framework would then track and analyze incremental learning across multiple players and games. In particular, multiple games would compete within the same topical domain. Using game score as an indicator of domain knowledge, games would be assessed by comparing pre and post-game performances on other games. Thus, the games themselves would provide a robust indicator of each other's efficacy and associated retention. As new games were introduced and competed in the framework, some games would "bubble up" as high-impact instructional vehicles, while others would naturally drop out of the fold. Thus, players would be competing with other players for high scores, and games would be competing with other games for learning efficacy. Games that result in fastest learning and highest player retention would be earmarked for pedagogic use. In general, any approaches or combination of approaches that support the stated objective are welcome.

PHASE I: Investigate extensively the existing body of research in psychology and education to determine and support empirically the characteristics of a suitable gaming framework, focusing on motivation, engagement, and instructive value. Identify any existing frameworks that embody those characteristics. Define clearly the methodology and metrics that would be used to assess learning efficacy in Phase II.

PHASE II: Develop a prototype of the game development and assessment framework. Develop instructionally rich, engaging games and then assess game-specific learning efficacy by analyzing players' performances across those games. Empirically demonstrate that the approach indeed selects for games with the highest learning value as suggested by the Phase I investigation.

PHASE III DUAL USE APPLICATIONS: The development of video game-based pedagogic tools that are as compelling as video games today could have a wide range of applications in both the federal and private sectors, including primary and secondary education, military training, corporate training, and self-improvement. In all cases, it is expected that learning time would be reduced, skill and content acquisition improved, and overall costs reduced.

REFERENCES: 1) The 3D Gamemaker, available online (2006): <http://t3dgm.thegamecreators.com>.
2) Bourge, C. & McGonigle, D. (2006), From Gaming to Training, Military Training Technology Online Edition, Vol. 11, Iss. 3, available online: <http://www.military-training-technology.com/article.cfm?DocID=1722>.
3) DARPA Information Processing Technology Office (IPTO), available online: <http://www.darpa.mil/ipto/>
4) Deci, E. L., & Ryan, R. M. (1985). Intrinsic Motivation and Self-Determination in Human Behavior. New York: Plenum.
5) Paul, R. (2006), Are player-driven games the future of digital gaming? ars technica, available online: <http://arstechnica.com/articles/culture/player-driven.ars>.
6) Stagecast, available online (2006): <http://www.stagecast.com/creator.html>

KEYWORDS: Simulation, Electronic Training, Gaming Framework, Genetic Algorithm, Education, Video Game

SB072-013 TITLE: Validating Large Scale Simulations of Socio-Political Phenomena

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Research, develop, and demonstrate new technologies for validating and verifying large-scale, socio-political simulations to assure reliability, understandability, and usability as analysis, planning, and monitoring tools for national security applications.

DESCRIPTION: Technology to assess and evaluate large-scale software systems is required to validate and verify large-scale socio-political simulations. This technology must examine the semantic structure and dynamic operation of the system, assist users in seeing not only how the system makes decisions, but what decisions it has made for a particular input configuration, and correlate the simulation results with real world data.

The technology should support semi-automatic extraction of the meta model from the source code, and comparison and evaluation of the meta model with the designer's model representation. Metrics assessing the 'goodness of fit' of the implementation to the model are required.

Validation is the process of determining if the simulation produces results that correlate with real world events. It is usually achieved through calibration of the system and comparing simulation results to known real world data. For large scale simulations, it is impossible to test every input parameter scenario. Moreover, stochastic influences can yield an exponentially large set of alternatives at critical decision points. Tools are required to semi-automate the process of testing a system given its meta model. Working backwards from an output configuration, these tools should determine a test suite that provides the greatest coverage in testing the decision paths through the system and determine what input parameter configurations induce the greatest sensitivity in the output configurations.

It is insufficient for a model to just predict a pattern of events or behaviors from its input; it must also explain how it derived this pattern. Validation of a simulation must be in terms of the sequence of decisions (and computations) that it made to arrive at the answer. Often, variations in predictions are dependent on second and third order effects.

Output is derived from lengthy, complex chains of inferences and computations. Tools are required to assist users in visualizing these chains and the intermediate states that a system traverses to produce an output and to generate explanations (using meta models) that describe how the system achieved the resulting output configuration. Given real world event data, the tools should be able to “walk back through” the model to determine what input configurations could generate those results, characterize the differences between the simulation’s results and the real world data, and assess the sensitivity of the simulation to variations in the input data configurations.

PHASE I: The contractor shall develop novel approaches for (1) extracting a meta model from existing simulation code that is expressible in a formal representation to be used in automatically developing test suites, and (2) augmenting existing simulation code to visualize control and decision flow through the simulation. Feasibility must be clearly demonstrated during this phase.

PHASE II: The contractor will implement tools based on the concepts developed in Phase I to (1) extract meta models and generate automated test suites for large-scale socio-political simulations, and (2) augment large-scale software systems to provide the user with better insight and understanding of the control and decision flow within the system. The contractor shall demonstrate the technology using an existing large-scale simulation such as Simulex’s SEAS, Sentia’s SENTURION, or Silverman’s PMFServ, but is not restricted to these systems. The contractor must justify the choice of a particular simulation as to its applicability and utilization by the DoD.

PHASE III DUAL USE APPLICATIONS: Many of these simulations can have dual-use capability: to support analysis and planning, but also to act as real-time monitoring/forecasting capability given appropriate data feeds. In either case, continuous assessment and evaluation of the simulations is necessary as they execute using different sets of parameters. The technology developed in this effort can support the continuous assessment of a system employed as a real-time monitoring/forecasting system. This technology will also have wide applicability in assessing and evaluating software systems other than simulations.

REFERENCES: 1) DoD 5000.61, DoD Modeling and Simulation (M&S) Verification, Validation, and Accreditation (VV&A), dated May 15, 2003
2) Chaturvedi, A.R., M. Gupta, S. Raj Mehta, W.T. Yue. 2000. Agent-based Simulation Approach to Information Warfare in the SEAS Environment, Proceedings Hawaii Int’l Conference on System Sciences, <http://ieeexplore.ieee.org/iel5/6709/20043/00926647.pdf>
3) Abdollahian, M., M. Baranek, B. Efird, and J. Kugler. 2006. SENTURION: A Predictive Political Simulation Model, http://www.ndu.edu/ctnsp/Def_Tech/DTP%2032%20Senturion.pdf
4) Silverman, B. (181 page tech report abstracting the PMF/HBM literature and assessing its validity for reuse in simulations), <http://www.seas.upenn.edu/~7Ebarryg/HBMR.html>

KEYWORDS: Applied Simulation, Validation, Verification, Computational Social Science, Explanation, Visualization.

SB072-014 TITLE: Handheld Transcription Device for the Hearing Impaired

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Design, validate, integrate, and demonstrate a prototype handheld device providing speaker-identified speech-to-text transcription of multiple English-language speakers in noisy environments.

DESCRIPTION: Hearing impaired individuals, even if they have some hearing and/or can read lips, may have significant difficulty following multiple English speakers in noisy environments. A handheld device that would display on a screen, the words of “Speaker1:<TRANSCRIBED TEXT>”, “Speaker2:<TRANSCRIBED TEXT>”, “SpeakerN:<TRANSCRIBED TEXT>”, would be of great benefit for such individuals. In providing this capability it is very important to meet certain performance goals:

- a) Latency: Speech must be transcribed and displayed with minimum delay, ideally no more than 100 milliseconds after utterance.
- b) Speaker Identification: Speech must be identified with the correct speaker (previously identified or new) with as high a probability as possible, ideally with 95% accuracy.

c) Speech Transcription: Individual words must be transcribed correctly with as high a probability as possible, ideally with 95% accuracy.

Note that these goals are for common conversational English sentences in environments with low background noise levels, e.g., an office conference room meeting. Performance is expected to suffer if more specialized vocabularies are allowed and in environments with higher levels of background noise.

PHASE I: The contractor shall identify algorithmic approaches, simulate these using standard commercial simulation tools and realistic speech inputs, and generate performance predictions for an integrated system that provides (1) speaker identification in noisy environments; and (2) speaker-identified transcription of English speech to English text in noisy environments. The contractor shall further assess the computational feasibility for these algorithms, when implemented in optimized software, to execute in real time on commodity processor hardware. The algorithms identified, results of the performance predictions for these algorithms, and the associated computational feasibility assessment will be described in the study delivered at the end of Phase 1.

PHASE II: The contractor will implement the approaches shown feasible in one or more operational prototypes for assessment by hearing-impaired users and iterative refinement.

PHASE III DUAL USE APPLICATIONS: The technology developed under this SBIR can be commercialized by industry (including the medical device manufacturers and the electronics industry) for use by both military veterans and civilian individuals who are hearing impaired whether it be as a result of military operations, accident, or birth defect.

REFERENCES: 1) "Hearing loss is a growing problem for veterans", Steve Liewer, San Diego Union-Tribune, January 9, 2006. <http://www.signonsandiego.com/news/military/20060109-9999-1n9hear.html>

2) "Noise and Military Service: Implications for Hearing Loss and Tinnitus", Larry E. Humes, Lois M. Joellenbeck, and Jane S. Durch, Editors, Committee on Noise-Induced Hearing Loss and Tinnitus Associated with Military Service from World War II to the Present, National Academies Press, 2005. http://newton.nap.edu/openbook.php?record_id=11443&page=R1

KEYWORDS: English, Speech-To-Text, Transcription, Multiple Speakers, Hearing Impaired, Handheld Device, Noise.

SB072-015 **TITLE:** Simulation Center in a Box

TECHNOLOGY AREAS: Information Systems, Human Systems

OBJECTIVE: Create the capability to train a maneuver battalion, using their organic battle command systems that can fit into a suitcase portable enough to be carried on a commercial airliner.

DESCRIPTION: Today, most battle simulation centers involve dozens of computers at fixed facilities and require a great deal of contractor support to maintain and operate the center. The Army and Marine Corps are deployed to hundreds of countries around the world, in many cases in small units. These forces deployed at remote locations do not have access to simulation capabilities, either for training or mission planning or rehearsal.

The goal is to address this deficit with a "Simulation Center in a Box". Responders need to propose a complete system, consisting of compact computing platforms, appropriate display and user input/output (I/O) solutions, communications, and software that can run a validated simulation system (such as the Joint Semi-Automated Forces (JSAF) or OneSAF Objective System) to simulate a battalion and an appropriately-sized opposing force that could fit into a case small enough to carry onto a commercial airliner. Operationally, the concept is that the simulation center operator (perhaps a single person) would arrive with the "simulation center in a box," set it up in a conference room, mess tent, or other facility, and be ready to conduct training within an hour. This does not include the time necessary to build the training scenario, which could be done in advance.

The simulation chosen must support both "conventional" warfare and the asymmetric warfare that characterizes much of the contemporary operating environment. The simulation must also interact with the battle command

systems typically found at ground maneuver battalions: Maneuver Control System (MCS), All Source Analysis System (ASAS), Air Missile Defense Workstation (AMDWS), Advanced Field Artillery Tactical Data System (AFATDS), Future Battalion Command Brigade and Below/Blue Force Tracking (FBCB2/BFT), and Command and Control Personal Computer (C2PC). (Time needed to reconfigure battle command systems is also not included in the desired "one hour" setup time, but bidders must show how they would estimate the time needed to do so and how their solution would minimize that time.) Finally, the simulation chosen must minimize the number of operators ("pucksters") needed to operate the simulation once deployed.

While development of the training scenario could be done in advance, the desire is for the "simulation center in a box" to be capable of beginning training within one hour of arrival. As a result, DARPA envisions that the system will use commercial wireless networking capabilities to link the devices. The study must address the security implications.

Besides the primary training function, the "simulation center in a box" must include support for evaluating the training exercise, including training logs, transcripts, after-action reports, and other appropriate take-away material. In addition, evaluation information should be complete enough to provide feedback to improve the exercise and training scenario itself.

The proposed capability must be capable of running from Army power generators or commercial 110 V. or 220 V. AC power. It must also be capable of running for one hour without external power to be robust against vagaries of local power generation. Ideally, if the system requires periodic battery recharge, the system's carrying case should act as a cradle for the entire system, so that a single power cord from the case could be plugged into the wall to recharge all system components at the same time.

PHASE I: Conduct a feasibility study, including recommendations on hardware, software, bandwidth and security requirements. The study must describe the analysis of what simulation would be most applicable, addressing issues of contemporary operating environment representation capability, validation and verification, operator overhead, training requirements, and evaluation requirements.

PHASE II: Build the prototype "Sim Center in a Box" and conduct a battalion training event using this device.

PHASE III DUAL USE APPLICATIONS: It is envisioned that this capability could also be used to bring simulation capabilities to smaller police and fire departments that cannot afford organic training capabilities.

REFERENCES: 1) Surdu, J.R., One Semi-Automated Force (OneSAF) Objective System (OOS): Program Overview
www.amso.army.mil/smart/conf/2006/4may06/Breakout%201-M&S%20Tools/OOS,Small_Common_v10.ppt

KEYWORDS: Training Simulation, Deployable, Portable

SB072-016 TITLE: Hierarchical Situation Visualization

TECHNOLOGY AREAS: Information Systems, Battlespace, Human Systems

OBJECTIVE: Develop technology for the visual representation of battlefield situations at multiple levels of abstraction appropriate for multiple levels of command.

DESCRIPTION: Today air-, space-, and surface-based intelligence, surveillance, and reconnaissance (ISR) assets deliver an enormous amount of data that commanders and their staffs must interpret to assess the combat situation. A technology gap exists between this data, usually displayed as raw feeds from each ISR system, and a coherent visual interpretation of the combat situation. The human brain is well adapted to combining and filtering the signals from multiple sensory modalities, and emerging evidence from neuroscience suggests this ability may originate from the hierarchical architecture in the frontal cortex [1]. DARPA is interested in the application of hierarchical architectures to situation awareness, as a means of visualizing the content from multiple, heterogeneous battlefield ISR assets. It is envisioned that Hierarchical Situation Visualization (HSV) technology will process the data from

multiple feeds to dynamically route and/or aggregate content to the appropriate staff in the chain of command. For example, HSV use the same sensor data to display events at the tactical level (e.g., platoon moving north) at multiple locations as well as events at an operational level (e.g., company retreating), and strategic level (e.g., enemy consolidating control). HSV will present these interactive operational pictures adapted to the user's objectives and command responsibilities (e.g., company, battalion, brigade) and be sensitive to low-level surprises that warrant high-level attention. Alternative human computer interaction modalities (e.g., immersive environments, virtual reality, haptics) are of interest for this effort. Proposers are encouraged to employ operationally realistic agent based combat model simulations (e.g., Joint Semi-Automated Forces (JSAF), air warfare simulation model (AWSIM)) for design and development of HSV technology. If applicable, proposers should also describe prior technology experience with fusing or visualizing data from extant heterogeneous ISR systems.

PHASE I: Investigate design approaches leading toward a Hierarchical Situation Visualization prototype. Identify the critical technical challenges involved in development of HSV technology. Select promising approaches and demonstrate viability through experimentation with combat model simulations. Evaluate potential benefits to commercial and military applications through system analysis.

PHASE II: Apply Phase I results, data, and analysis to develop a prototype that demonstrates the efficacy of HSV technology. Perform prototype experiments with combat model simulations and evaluate the assistance of subject matter experts in military command and control.

PHASE III DUAL USE APPLICATIONS: Development of HSV technology would result in a significant enhancement to military situation awareness capabilities. The algorithms and visual interface technologies also has potential commercial application for enterprise knowledge management.

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KEYWORDS: Situation Awareness, Data Fusion, Neuroscience, Modeling, and Simulation.

SB072-017 TITLE: Contextually Adaptive False Alarm Mitigation

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Identify and develop adaptive methods for using the context of an urban battlespace to reduce the false alarms generated by an airborne target detector.

DESCRIPTION: Target detection systems in Intelligence, Surveillance, and Reconnaissance (ISR) platforms use motion and shape features to form decisions about the presence of a target (vehicle or dismounted combatant). These processes are adept at detecting targets, but frequently generate too high a false alarm rate to be useful. Processing methods are needed that can take advantage of other information in the urban environment such as proximity to buildings and roads, traffic patterns, etc to mitigate high false alarm rates. A number of approaches that use context to reduce the false alarms have been developed. However, the approaches to date all need detailed urban models and/or complex rules for target behavior. This makes them brittle in an operationally dynamic situation. To be useful for real-world applications, the contextual rules that drive the processing methods need to be rapidly derived for observation and not rely on exquisite knowledge of the urban terrain.

PHASE I: Define context derivation methods that can quickly converge on context rules that are adaptive to the observed behavior. Simulate a processing system that is fed by low complexity detectors and uses contextual processing to achieve a significant reduction in false alarm rate while still preserving a high probability of detection. The sensors of principal interest are electric optical (EO) and infrared (IR).

PHASE II: Demonstrate the system operation in multiple changing urban situations

PHASE III DUAL USE APPLICATIONS: The technology developed under this SBIR has homeland security applications such as border surveillance or in security surveillance/protection.

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KEYWORDS: False Alarm Reduction, context, Imagery, EO, IR

SB072-018 TITLE: Computationally Efficient Parallax Processing

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Identify and develop methods to accommodate parallax effects in imagery observed from a moving platform.

DESCRIPTION: Many processes in Intelligence Surveillance and Reconnaissance (ISR) systems require images to be stabilized and registered to previous/historic images. When the ISR platform is stationary, only camera motion needs to be accounted for. When the ISR platform is moving however, the different points in the image appear to move at different rates due to differences in distance from the camera. Methods to accommodate this effect have been developed that use representations of the 3D environment to predict and correct for parallax in the image registration process. These methods are computationally expensive and do not map well to off the shelf processors. DARPA is looking for approaches to image registration in the presence of parallax that can be implemented in real time (5-30Hz) in commercially available processing hardware.

PHASE I: Using laboratory image data, design and simulate a technique for image registration in a high parallax environment. Conduct an analysis of the processing requirements and show a plan for implantation in standard Graphics Processing Unit/ Central Processing Unit (GPU/CPU) systems.

PHASE II: Demonstrate image registration including the removal of parallax effects operating in real-time utilizing data from a low altitude unmanned air vehicle (UAV).

PHASE III DUAL USE APPLICATIONS: The technology developed under this SBIR has homeland security applications such as border surveillance.

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KEYWORDS: Image Registration, Parallax, Real Time

SB072-019 TITLE: Wide Area Video Image Storage Techniques

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop methods for storing data from wide area video sensors.

DESCRIPTION: Emerging sensors have the ability to cover large areas at high resolution. The volume of imagery that can be generated is staggering. For example a one giga-pixel sensor operating at 10 Hz with 12 bits of dynamic range per color on a three color sensor would generate about two petabytes worth of data over a 12 hour mission. If all the data were to be stored, in an uncompressed or losslessly compressed manner it could require up to 1000 terra byte hard drives for a single surveillance mission. Two of the main issues associated with data compression are the computational time required to compress the data and compression artifacts. Examples of the types of artifacts that appear from lossy compression algorithms in staircase noise along curving edges, contouring along otherwise smooth gradients, elimination of small objects. DARPA is looking for computationally efficient innovative methods for taking advantage of mission profiles to reduce the storage requirements by at least two orders of magnitude without introducing image artifacts into the stored data. There are two mission profiles of primary interest, the first having the sensor mounted on a pseudo-stationary, i.e., very slow moving platform, staring at the same area. The second having a sensor on a platform that is orbiting an area staring at the same region.

PHASE I: Using laboratory image data, design and simulate a technique for solving the image storage problem in a computationally efficient manner. Conduct an analysis of the processing requirements and show a plan for implantation in standard Graphics Processing Unit (GPU)/Central Processing Unit (CPU) systems and/or alternative cost affordable hardware, e.g., Field Programmable Gate Arrays (FPGA)/Field Programmable Operational Arrays (FPOA).

PHASE II: Demonstrate the image storage solution operating in real time in conjunction with a wide area sensor. The sensor will be chosen by DARPA.

PHASE III DUAL USE APPLICATIONS: The technology developed under this SBIR will have application in fixed site security surveillance systems as well as homeland security applications such as border surveillance.

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KEYWORDS: Storage, Wide Area Surveillance

SB072-020 TITLE: Anomaly Detection and Intelligent Sensor Resource Management

TECHNOLOGY AREAS: Information Systems, Sensors

OBJECTIVE: Develop sensor resource management, data exploitation and classification algorithms for the automatic detection of anomalous activities in cluttered environments using imaging and moving target indication (MTI) sensors.

DESCRIPTION: The idea of using data products from existing and future intelligence surveillance and reconnaissance (ISR) systems to develop models of normal background activity, i.e. modeling the clutter, has received considerable interest of late. The use of these normalcy models should allow for the detection of anomalous events which can be subsequently investigated to determine their military significance. Innovative system concepts which support closed-loop sensor control for unsupervised training and application of anomaly detection algorithms are encouraged. These concepts should provide a solid theoretic framework for control,

modeling and detection and be adaptable to various applications including urban ground surveillance using combinations of ground, air and space-based radars, electro-optical and infrared images and MTI.

PHASE I: Develop or adapt modeling and simulation resources to quantify the capabilities of the proposed system to characterize normal activities and detect anomalous events. Specifically quantify the capabilities of the system to detect and characterize according to the nature of the anomalous behavior observed. Develop a system concept and conduct the relevant performance tradeoff analyses.

PHASE II: Develop a prototype system based on the Phase I concept suitable for field testing. Demonstrate the performance of the system against wide ranges of normal and anomalous activities. Demonstrate the capabilities of the system to reactively define "normal" based on the context as sensed and based on macroscopic situational parameters, i.e. geographic location, operational context and local cultural norms. In the event the proposed system concept involves sensors beyond the control of the bidder, develop and execute a test plan in cooperation with the Government. Pursue technology insertion opportunities into current and future military ISR systems.

PHASE III DUAL USE APPLICATIONS: The system and/or technology could potentially be employed in numerous military ISR systems including ground-based, air- and space-borne assets. The technology would afford the military a new and/or improved capability to detect and anticipate enemy activities within an environment cluttered by friendly or neutral activities. Potential commercial applications include remote sensing for homeland security and law enforcement.

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KEYWORDS: Anomaly Detection, Normalcy Modeling, Statistical Pattern Analysis, MTI, Sensor Resource Management.

SB072-021 TITLE: Ultra-Light Interlaced Active Electronically Steerable Antennas (ULI-AESA)

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Develop an ultra-lightweight interlaced (shared aperture) active electronically steerable antenna (AESA) with integrated transmitter/receivers which can be produced at very low manufacturing cost. The AESA system should be applicable to airborne radars designed for small unmanned aerial vehicles (UAVs) and provide for simultaneous operation at both millimeter-wave and microwave frequencies.

DESCRIPTION: In order to affect low-cost radar sensors for small high-endurance UAV's, ultra-lightweight AESA technology is required. Payload capacities on-the-order-of 10 lbs and 100W afford limited active antenna system weight and require relatively high efficiencies. It is expected that significant improvements in AESA-receiver weights and power-efficiencies can be obtained by employing radio-frequency integrated circuit (RFIC) technology which has recently been enabled by the now sufficiently high gain-bandwidth product (fT) of current and future semiconductor materials and processes, i.e. silicon germanium (SiGe) and complementary metal oxide semiconductor (CMOS). Due to the limited prime power available on small UAV's, AESA power density requirements are constrained to be low and system performance will rely on large antenna areas. Conformal or structurally integrated AESA technologies are of most interest to allow for efficient utilization of available UAV surface area. Integrated receivers which provide digital outputs are of most interest. The operating frequency can be traded for antenna area and RF power; operation in the X, Ku, Ka, V or W bands is of most interest. Antenna technology which allows for simultaneous interlaced (shared aperture) low-band operation is also of interest, e.g. L and S-bands.

PHASE I: Using high-fidelity modeling and simulation tools, conduct a feasibility study for a prototype antenna-receiver system. The study results should demonstrate the ability to meet the electrical and mechanical constraints determined during an early tradespace analysis and agreed upon by DARPA.

PHASE II: Design, fabricate and test the prototype active antenna system. Demonstrate that the prototype antenna system meets the electrical and mechanical specifications determined during the Phase I feasibility study. Pursue, in collaboration with DARPA and other Government agencies, technology insertion opportunities into current and future military ISR systems.

PHASE III DUAL USE APPLICATIONS: The system and/or technology could potentially be employed in future military and/or commercial ISR and communications systems including ground-based, air- and space-borne assets.

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KEYWORDS: Antenna, Active, Array, AESA, Receiver, RFIC, Manufacturing.

SB072-022 TITLE: Optical Localization Techniques for Micro-Sensor Network Devices

TECHNOLOGY AREAS: Information Systems, Sensors, Electronics

OBJECTIVE: Identify and develop innovative technologies to enable optical localization of micro-sensor network devices.

DESCRIPTION: The exploitation of wireless sensor networks very often requires knowledge of the location of each device within the network. Current technologies have advanced the processing power and communications range of devices such that a network may consist of a large number of nodes (possibly hundreds of thousands) deployed over a large area (possibly tens of square miles). Such deployments support operations such as wide-area surveillance, tracking of activity, and the detection and classification of assets. An accurate method of determining each node's precise location within the network significantly improves the value of the data collected by the sensor network. This capability supports an ad-hoc deployment of nodes (eliminating the need to deploy nodes to precisely known locations) and reduces the need to "touch" each node once deployed. One approach to localizing a network of sensors makes use of controllable light sources and the image measurements derived from embedded smart camera systems. This approach allows the network to determine the relative positions and orientations of the smart camera nodes as well as the locations of other sensor nodes in the ensemble. This effort would involve the development of methods to estimate the relative position and orientation of a constellation of sensors based on optical measurements.

PHASE I: Conduct a feasibility study on optical localization techniques. Identify those techniques that may be beneficial to large-scale deployments of wireless sensor networks.

PHASE II: Develop a prototype optical localization system (algorithms, software, hardware) and demonstrate its use in an operationally-realistic environment. Conduct testing and evaluation of the system to prove its effectiveness to accurately determine the absolute position of nodes within a wireless sensor network.

PHASE III DUAL USE APPLICATIONS: This technology has both military and commercial applications for wireless sensor networks. For military use, it will increase the ability to deploy wireless sensor networks without putting warfighters or other assets in danger. For commercial use, it will reduce the time required to deploy and wireless sensor networks and maintain them once deployed.

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KEYWORDS: Optical Localization, Imagery, Wireless Sensor Networks

SB072-023 TITLE: Sensor-to-Symbol: Frameworks for Integrated Systems Research

TECHNOLOGY AREAS: Information Systems, Sensors

OBJECTIVE: Apply advanced frameworks for integrating intelligent software and sensor-processing components to create sensor systems that can flexibly modify their mapping of inputs into output categories in response to changes in observations, environmental conditions, or user requirements.

DESCRIPTION: The problem of mapping sensory input into discrete ontological categories is a fundamental challenge that must be addressed by any advanced sensor-processing system. The simplest of gauges map physical measurements into human-accessible categories, like “speed,” “temperature,” “RPM”, etc. In more complex sensor-processing, like automatic image analysis, the challenge of converting the many low-level bits of information into just a few user-relevant categories is greater. State-of-the-art systems are typically engineered to effectively solve narrow and relatively rigid instances of this problem in an application -specified fashion. When existing categories are insufficient and need to be extended, refined, or redefined, the situation must first be identified by people, usually end users or our warfighters, and then resolved by engineers in a process that can take months or even years. In adversarial situations, when opponents are actively seeking to modify and disguise the signatures of their equipment, the ability to recognize novel patterns in sensor data and reason about the cause and threat potential can be a decisive advantage.

As the number and type of sensors continues to grow, so does the need for adaptive algorithms that can learn the appropriate categories and categorical distinctions required by the end users and applications. This is a feature of higher-order intelligence that is essentially human: people can naturally extend, refine, and adapt their vocabularies with seemingly little cognitive difficulty. It has long been believed (e.g., [1][2][6]) that human-level intelligence such as this can be viewed as the product of an integrated suite of lower-level competencies, many of which embody some information-processing capability generally considered “intelligent” in its own right.

This topic seeks innovative research proposals that will build upon emerging software-integration frameworks and recent advances in cognitive engineering to integrate a variety of state-of-the-art intelligent competencies in ways that directly address the sensor-to-symbol problem. Potentially relevant examples of integration frameworks include service-oriented architectures, grid computing, agent-oriented architectures, and semantic integration. Cognitive architectures have been the focus of DARPA’s Architectures for Cognitive Information Processing (ACIP) program and there are a number of existing architectures that could plausibly serve as a baseline for integrating intelligent competencies in order to produce higher-order intelligence. References [3][4] and [5] each describe very different examples of such architectures.

The ideal proposal will seek to build upon existing frameworks to combine a variety of extant capabilities in order to address the fundamental sensor-to-symbol problem in a significant way, while also demonstrating the general-purpose nature of the approach to integration. As a hypothetical example, a thermal-imagery based sensor processing system could be capable of classifying various vehicle signatures. Assuming that it classified Humvees as friendly military vehicles, such a system may be confused by the altered signature presented by Hummers in civilian areas. A symbolic reasoner might be able to first note the discrepancy, then assess the possible explanations, potentially in a dialog with users, and then apply standard machine-learning techniques in an attempt to produce an accurate assessment of a Hummer as a civilian vehicle. If guerilla forces then begin to use Hummers for troop movements, the system might be able to use information about geo-location, the structure of convoys, and

common operating knowledge to produce an updated discrimination between the non-threatening use of Hummers and potential adversarial uses.

This effort will create a foundation for the construction of robust, user-centric sensor-processing systems that integrate large and diverse sets of advanced information-processing capabilities.

PHASE I: Assess feasibility of proposed technical approach by identifying key technical barriers, evaluating alternative solutions, and developing strategies to mitigate risk. Identify candidate competencies and produce a plan for incremental integration. Develop a plan for evaluating the overall ability of the system as well as the contribution of each capability to the observed quality.

PHASE II: Implement an advanced software prototype that integrates a variety of sensor and information processing capabilities into a single system that is capable of extending, refining, and redefining its set of classification variables.

PHASE III DUAL USE APPLICATIONS: The core sensor-to-symbol technology will have cost-savings potential in any sensor-based application, particularly those that require multi-sensor fusion. It will drastically reduce the cost and implementation time of changes in a sensor classification scheme. In an increasingly sensor-laden world, this could create significant flexibility in a wide variety of embedded applications that can not currently be modified or updated without significant costs. Military applications include target identification systems, missile warning systems, and chemical attack warning systems. Potential commercial applications include reduced-cost air traffic monitoring, adaptable home and building automation systems, and improved quality control in manufacturing systems.

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KEYWORDS: Sensor fusion, Software integration, Intelligent systems, Symbolic reasoning

SB072-024 TITLE: Integrated Waveguide Optical Isolators

TECHNOLOGY AREAS: Air Platform, Information Systems, Sensors, Electronics

OBJECTIVE: Prepare a Phase I feasibility study and technical approach that describes the necessary materials, processing, and manufacturing techniques to produce an optical isolator that can be integrated into optical waveguides, such as those made from semiconductors, glass, and polymers. The candidate isolator should be able to meet performance specifications of less than 3 dB insertion loss (including coupling into and out of the integrated isolator) and have 30 dB or more isolation. The isolators should have manufacturing tolerances consistent with commercial production. Isolator concepts that can operate in systems with wavelengths in the range of 1.55 to .83 micrometers are of interest.

DESCRIPTION: There is a widespread need for optical isolators in fiber optics, free space optical communication, and in photonic integrated circuits. Optical isolators used in communication systems have to date been bulk devices. There are presently no commercial optical isolators that can be integrated with miniature optical components such as semiconductor lasers or arrays of lasers. A number of papers describing isolators that can be integrated with optical waveguides have appeared in the recent literature, but with high insertion losses. [1,2] Innovative approaches for integration of an isolator with optical waveguides are sought under this topic. These approaches should be

compatible with semiconductor, glass and polymer waveguides. Technology developed under this topic should be complementary to and combinable with photonic integrated circuits.

PHASE I: The contractor will study the feasibility of novel approaches to integrate optical isolators with semiconductor, glass and/or polymer waveguides. The feasibility study should include analysis and/or simulations to determine the isolation, the insertion loss of the proposed isolator, and the input/output coupling losses of the isolator. The Phase I study should also address the manufacturability of the proposed isolator in terms of wafer-level processing.

PHASE II: The contractor will fabricate and demonstrate prototype isolators integrated into a semiconductor, glass or polymer waveguide based on the isolator technology proposed in Phase I. The insertion loss and isolation performance will be measured during the Phase II program. Fabrication and integration techniques to enable ultimate high volume manufacturing will be assessed. Military robustness and functionality should be evaluated.

PHASE III DUAL USE APPLICATIONS: The isolator technology developed under this SBIR topic is needed in military and civilian communications and computing applications that involve photonic sub-systems and photonic integrated circuits. Commercial applications include: optical interconnects at the intra-chip, inter-chip and inter-board levels, for future high end servers, routers, signal processors, and supercomputers. Military applications include optical communications networks from the chip-level and higher on many future military platforms.

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KEYWORDS: Optical Isolators, Waveguide Isolators, Integrated Isolators, Semiconductors, Polymers, Manufacturing, Nanofabrication.

TECHNOLOGY AREAS: Sensors, Battlespace

OBJECTIVE: Identify and develop innovative imaging optics that are integrated with micro-mechanical elements to enable rapid and random access scanning of a Focal Plane Array (FPA) over a wide field of regard, while significantly reducing the size, weight, and power compared to conventional scanning technologies. The new actuated imaging optics should also be able to achieve optical zoom.

DESCRIPTION: Increasing demands on the warfighter for situational awareness require optical imaging techniques to gather information over large fields of view. The ability to scan the imaging sensor enables significant reduction in the size of the optics. Furthermore, enhancement to system resolution is possible if the scanner has the capability to zoom in on the target or region of interest. Furthermore, reductions in cooling power requirements of a large FPA (to enhance sensitivity) could be made if one could scan the array. This is important for small platform applications such as, micro-air vehicles, robots, and “motes” (short for remote sensors that are connected via wireless transceiver.).

Currently, scanning and zooming of imaging optics is done with bulky mechanical gimbals or using multiple focal plane arrays and associated optics to cover the wide field of view. These approaches are not only expensive in terms of power, size and weight, but also costly.

Future military imaging systems need micro-actuators to perform functions such as tip, tilt, and zoom. This requires moving small mechanical loads such as mirrors or lenses and detector arrays. Innovative concepts are needed to enable the micro-actuator to scan the field of view over a wide field of regard (i.e., with scan angles of $>80 \times 80$ degrees), and be capable of delivering forces $>0.1\text{N}$ (Newton) and torques of $\sim 10^{-3}\text{ Nm}$ (Newton-meter). Technologies which have efficient transduction mechanisms in terms of the ratio of load/weight of the micro-actuator of >5 are highly desirable. The energy consumption should be $<10\text{ mJ/scan}$ (milli-Joules) to ensure that the energy expended by the actuators is smaller or comparable to the energy consumed by the optical sensor itself. The actuator should be capable of random access as this significantly enhances the military Concept of Operations (CONOPS). Another goal is to be able to achieve a frame rate for full $\pm 40^\circ$ scan of $<30\text{ms}$. The total weight of the micro-actuator should be $<20\text{ g}$ (grams) with a path to $<10\text{ g}$ in the future. As power for small platforms is always at a premium, technologies for the micro-actuator that require no standby power when they are not scanning and maintain their position when in the “off” position are of particular interest. Another feature which is highly desirable to be accommodated in the micro-actuator is an optical zoom function; zoom capability up to 5X is sought with collection apertures of $>2\text{mm}$ (millimeters).

There are numerous approaches which may be developed to achieve the desired specifications for a next generation imaging system micro-actuator. Innovative approaches are sought which can achieve all of the requirements simultaneously.

PHASE I: Prepare a feasibility study for the concept design for micro-actuated optics which has the capability of 80×80 degree scan angles, with 5X optical zoom and weight of $<20\text{g}$ and scan speed for the 80 degrees of $<30\text{ms}$. Assess the feasibility to achieve these goals by mechanical and optical simulations. As part of the final report, plans for Phase II will be proposed.

PHASE II: This phase will complete the detailed design from Phase I. A concept demonstration prototype shall be demonstrated. Fabrication techniques to enable ultimate high-volume manufacturing will be assessed. Operation over military temperature ranges and with shock and vibration should be assessed.

PHASE III DUAL USE APPLICATIONS: There are both commercial and military applications for this technology. Commercial applications include: medical and industrial inspection systems, and portable optical imaging systems. Military applications include: surveillance for unattended sensors/motes and robotics, imaging for missiles, unmanned airborne vehicles (UAV) based overhead surveillance.

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KEYWORDS: Sensor Array, Scanner, Wide Field of Regard, Optical Imaging, Manufacturing.

SB072-026 TITLE: Reliable MEMS Ka-Band Filters

TECHNOLOGY AREAS: Air Platform, Information Systems, Ground/Sea Vehicles, Materials/Processes, Sensors, Electronics, Battlespace, Space Platforms, Weapons

OBJECTIVE: Develop reliability data on Ka-band micromechanical Radio Frequency (RF)-filters that are both tunable as well as capable of narrow bandwidths and <2dB loss

DESCRIPTION: In today's densely populated RF-communication channels, proper allocation and management of spectrum is an overriding concern for US military forces. A shift to higher microwave and millimeter-wave frequencies has increased the available bandwidth for military radar and communications. However, this shift requires high-performance filtering to mitigate jamming and co-site interference. As these stringent requirements continue to require lower bandwidth filters, it becomes increasingly difficult to maintain reasonable loss and maintain high reliability. As a result of recent DARPA programs, reliability of MEMS RF-switches has been shown to be greatly enhanced by device level packaging and environment control. The highly reliable MEMS RF-switches hold promise for realizing tunable filters by implementing subcomponents such as phase shifters on integrated waveguides. In this effort, we seek demonstrations of not only MEMS RF-switch based filters, but also measured reliability data of such filters suitable for Ka-band RF electronics.

PHASE I: Develop a design and manufacturing plan to produce 500 MHz BW tunable filters in the Ka band. Develop a process flow to develop such filters with harsh environment packaging to ensure operation over military temperature ranges. Use the filter design to develop the specifications for power, weight, and performance of a DoD system, such as an Electronically Scanned Antenna used in RADAR or GPS receivers.

PHASE II: Fabricate and test filters designed in Phase I, and use the filters to realize a test-bed antenna to verify advantages in power, and weight. Prove reliability of filters by demonstrating >200 Billion cycle testing of each of the individual switches that are used to tune the filter.

PHASE III DUAL USE APPLICATIONS: MEMS RF-filters based on reliable MEMS RF switches have the potential of revolutionizing not just military RF electronics, but will also contribute significantly to revolutionary improvements in commercial applications such as collision avoidance in vehicles, GPS receivers in urban environments, and EM medical imaging.

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KEYWORDS: MEMS, RF-Switch, Tunable Filter, Ka-Band, Electronically Scanned Antenna, Materials Processing, Manufacturing.

SB072-027 TITLE: MEMS/NEMS High Temperature Thermal Barrier Coatings

TECHNOLOGY AREAS: Air Platform, Materials/Processes, Battlespace

OBJECTIVE: Develop micromachined thermal barrier coatings (TBC) to extend the performance, efficiency, and lifetime of micro combustion systems such as gas turbine engines

DESCRIPTION: Gas turbine engine temperatures have increased 1600°F in the last 60 years. A majority of that increase occurred between 1960 and 1980, when the inlet temperature grew at a rate of 55°F per year, yielding an 1100°F increase in turbine temperature during that span. Since that time, temperature increases have asymptoted to <5°F per year. This is of great significance because the inlet temperature for turbine engines directly relates to performance (specific power) and efficiency. Improved turbine blade thermal barrier coatings (TBCs) could increase specific power and reduce fuel and cost-of-ownership by billions of dollars. Current efforts on improving TBCs are based on ceramic spray coatings and advanced cooling of the turbine blades. The current methods focus on micron-scale thin film engineering, while it is clear that layer-by-layer nanoscale deposition of layers to form nano-layer composites may offer significant advantages. In addition, NEMS/MEMS engineered coatings could be engineered for different engine performance needs. The co-development of nano-composite films in addition to NEMS thermal isolation techniques will significantly increase inlet temperature of turbines by reducing thermal conductivity with minimal impact on overall weight of the turbine blade. NEMS/MEMS coatings can enable photon flux control, and can also control phonon flux using nano and micro scale thermal isolation structures. We seek chip-scale implementations of such thermal and optical isolation that could be tiled on turbine blades for a cost effective improvement in engine operating temperature.

PHASE I: Develop models to predict the decrease in the thermal conductivity of a MEMS TBC. Design a MEMS TBC with factor of four reduction in thermal conductivity. A plan to conduct experimental verification of models will be prerequisite to obtaining Phase II funding.

PHASE II: Fabricate MEMS TBC and quantify the thermal barrier properties at high temperatures. Demonstrate that the MEMS TBC has a decrease in thermal conductivity of a factor of four, in realistic combustion settings.

PHASE III DUAL USE APPLICATIONS: NEMS/MEMS engineered TBC have an enormous application in improving gas turbine engines in both the military and civilian markets. While military applications often use higher performance gas turbine engines that can be vastly improved in performance (e.g., high speeds) and efficiency (e.g., range of aircraft), there may be an even larger potential impact in commercial aviation due to fuel savings and reduction of noxious exhaust gases.

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KEYWORDS: MEMS, NEMS, Thermal Barrier Coatings, Gas Turbine Engines, Materials Processing.

SB072-028 TITLE: Negative Index Materials for High Resolution Photolithography

TECHNOLOGY AREAS: Materials/Processes, Electronics

OBJECTIVE: Identify and develop innovative technology to enable higher resolution optical lithography at the 193 nm wavelength.

DESCRIPTION: Optical lithography is the standard for the commercial production of semiconductor chips and circuit processing because of its high wafer throughput. However, as the needed resolution decreases with each manufacturing generation, new light sources, materials and methods need to be developed. Current research to improve the resolution of optical lithographic techniques have centered on immersion lithography which is limited by the lowest refractive index of the components of the system including the final lens, the immersion fluid, and the photoresist. Improvements above the current state of the art are challenging. In addition, phase shift masks and optical proximity corrections are needed to correct for diffraction effects to further improve the resolution, but these are quite complex and require extended processing time.

The aforementioned diffraction effects are intrinsic to all positive index material techniques. Recently the use of a negative index material (a material with negative permittivity and susceptibility) has been shown to exhibit 60 nm half-pitch resolution using 365 nm light without the use of optical correction techniques. These materials focus, rather than diffract, the light due to their negative refraction of light. Extension of these materials to 193 nm light will enable sub-diffraction lithography using the currently available light sources and photoresists without any immersion technique or any complicated phase generated masks, thus decreasing the cost and design time for semiconductor wafers, and extending the lifetime of the current manufacturing tools.

PHASE I: Identify negative index materials that have the potential to produce high quality images at 193 nm.

PHASE II: Develop the materials and integrate into a lithographic processing system at 193 nm and demonstrate a proof-of-concept.

PHASE III DUAL USE APPLICATIONS: The technology developed under this SBIR can be used in military and civilian commercial optical systems requiring sub-diffraction limited resolution optics, including medical microscopy.

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KEYWORDS: Negative Index Materials, Optical Lithography, Material Processing.

SB072-029 TITLE: Electro-Optic Polymer Based Ultra-Linear Directional Coupler

TECHNOLOGY AREAS: Sensors, Electronics

OBJECTIVE: Design, fabricate, and demonstrate a low optical loss polymer directional coupler modulator which has a fiber to fiber optical loss that does not limit device performance across a range of frequencies.

DESCRIPTION: Microwave/millimeter wave technology is presently a mature technology. Monolithic components allow for high signal to noise ratios to be achieved. However, the necessity of down conversion from the high frequency carrier to an intermediate frequency before digitization and/or further processing limits the effective dynamic range that can be achieved by purely microwave/millimeter components.

The development of low dispersion and low loss optical links coupled with the linear response of optical detectors to the intensity of incident light stream would make optical links a quite attractive alternative to microwave/millimeter links. These technologies could be employed in remote transmission and signal preprocessing if the optical intensity modulator can be made to match the rest of the optical system and optical to microwave/millimeter wave down conversion.

PHASE I: Feasibility study to demonstrate low-optical loss polymer materials with r_{33} values on the order of 100 pm/V and an optical loss of ~ 2 dB/cm.

PHASE II: Prototype polymer modulators with high r_{33} , low optical loss materials and demonstrate the following: (1) polymeric materials with optical loss less than 1.5 dB/cm, (2) demonstrate a 2x decrease in the dc drift over state-of-the-art LiNbO₃ optical modulators and switches, (3) demonstrate low loss coupled links as part of

modulator design and (4) demonstrate scalability of the design and process for fabricating selected modulator devices and materials.

PHASE III DUAL USE APPLICATIONS: The military applications of this technology include improved broadband performance of modulators for communications and radar systems. Commercial applications will be primarily focused on improved bandwidth for communications infrastructure and equipment as well as communication electronics.

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KEYWORDS: Polymer Modulators, Low-Loss Optical Polymer Materials, Multi-Stack, Polymer Waveguides.

SB072-030 **TITLE:** Scalable-Network Wireless Imaging Sensors for the Battlefield

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: To design and develop novel adaptive and scalable wireless video sensor networks functioning in a multi-frequency environment, for applications in real-time battlespace situational awareness and surveillance. The long-term goal will be to achieve automatic threat detection by image processing alone, immediately at the sensor for initial identification, and subsequently at the network base-station for substantive analysis and warning, with very low false-alarm probability and high probability of detection.

DESCRIPTION: The application of current wireless sensor networks is concentrated on non-imaging technology that generally provides only acoustic, seismic and magnetic data, and therefore is likely to have high false alarms and low probability of detection. The addition of wireless video transmission would enhance the effectiveness of these non-imaging sensor networks and mitigate their deficiencies. Wireless video sensor networks also would provide superior battlefield situation awareness and surveillance capabilities. This topic would solicit designs and development of wireless video sensor networks capable of covering large areas while collecting streaming video data back to command stations. Innovative network protocols, adaptive architectures, compression and transceiver techniques, bandwidth traffic management, reconfigurable network communication and other novel approaches will be established under this topic.

PHASE I: A Phase I effort would study the feasibility of achieving the integration of technologies for a wireless video sensor network. This preliminary effort would concentrate on requirements to accommodate the sensors' streaming data, with equal emphasis on power conservation and network efficiency.

PHASE II: The components for these networks, such as transmitters, receivers, and repeaters, will be designed and assessed in simulations of the network performance. Their functionality will be validated, and some degree of intrusion-identification will be provided at the imaging nodes. A demonstration of the effectiveness of imaging sensor networks, compared to prior non-imaging sensors, will be given.

PHASE III DUAL USE APPLICATIONS: Wireless imaging sensors will be useful for fielded military applications, and be very applicable to a wide variety of situations where you would want a "human-like" visual capability to judge if some event has occurred. For example, home protection needs such a sensor network to detect intruders when the occupants are absent (but ignoring movements of the dog and cat.)

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KEYWORDS: Automatic Target Recognition; Mesh Communication; Multi-Frequency Transceiver; Wireless Streaming Video; System-On-A-Chip; Scalable Network Architecture.

SB072-031 **TITLE:** Physically Small Superconducting Antennas

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: To develop a physically small (much, much less than the wavelength of interest) antenna system capable of operating in the 3 to 30 MHz frequency range while environmentally noise limited and capable of performing direction finding in a dense environmental noise scenario.

DESCRIPTION: Current techniques for direction finding of incident signals in the high frequency (HF) band (3 to 30 MHz) require antennas that are a significant fraction of a wavelength and which are separated by a distance comparable to a wavelength, which at 3 MHz is 100 meters while at 30 MHz the wavelength is 10 meters. It is not feasible to deploy such systems on mobile platforms, such as trucks, tanks, unmanned autonomous vehicles and planes, the dimensions of which are typically smaller than the wavelength of interest, particularly at the low end of the HF band.

The objective of this topic is to explore and demonstrate the use of cryogenically cooled superconductive Josephson junction technology (capable of operating at temperatures in the vicinity of 77 K) in the fabrication of physically small antennas with dimensions of the order of several inches or less (excluding the cryogenic enclosure) that are capable of environmental noise limited reception in the band of interest, that can detect weak signals in the presence of very intense interfering signals, both in band and out of band, with the objective of demonstrating a dynamic range of the order of or greater than 140 dB per Hertz and that can perform direction finding on weak signals to an accuracy of several degrees or less.

Previous research activities have demonstrated that environmentally noise limited detection can be achieved using superconducting loop antennas, with areas of several square centimeters, when superconducting amplifiers employing Josephson junctions have been used to detect the signal induced in the loop antenna by the incident radiation. A variety of Josephson junction based amplifier configurations have been examined including single Superconducting Quantum Interference devices (SQUIDs) (a superconducting circuit containing two Josephson junctions), series arrays of SQUIDs, series-parallel arrays of SQUIDs, (commonly known as Superconducting Quantum Interference Filters (SQIF), a superconducting parametric up-converter amplifier employing a large number of SQUID inductively coupled to a superconducting transmission line, and a long Josephson junction (known as a Josephson Fluxon Anti-Fluxon Transistor (JFAT)). All of these configurations for Josephson junction amplifiers exhibit gain and exceptionally low front-end noise over various frequency bands from DC to greater than 20 GHz. However, there has been only very limited research (except for the case of an amplifier employing a single SQUID) on the dynamic range and Spur Free Dynamic Range of these Josephson junction based amplifiers. This latter research is crucial for the use of Josephson junction based amplifiers in dense noise environments.

Furthermore, these superconductive loop antenna systems have not been configured for performing direction finding on a very short base line.

The ultimate objective is to fabricate and evaluate, as a function of array complexity, various Josephson junction-based amplifier configurations for HF DF applications in dense environments and to down select the configurations which are deemed to be most promising for more detailed evaluation in a simulated operational environment.

PHASE I: The Phase I effort should involve the compilation of the reported characteristics of various Josephson junction-based amplifier configurations (that are capable of operating at temperatures in the vicinity of 77 K), which might be suitable for HF DF applications. The most promising ones shall be selected, designs developed for amplifiers based on these configurations and mask sets designed to fabricate these amplifiers with various levels of complexity. This would establish the proper scaling laws for the amplifier response in terms of gain, noise, single tone dynamic range and Spur Free Dynamic Range.

In this Phase, detailed test plans shall be prepared for full evaluation of these devices, both in the laboratory and then in a simulated operational situation at an outdoor test range.

PHASE II: In Phase II, mask sets will be designed and chips fabricated to evaluate and characterize the selected amplifier configuration as a function of complexity to optimize reception sensitivity, gain, single tone dynamic range, and Spur Free Dynamic Range. The devices with the most desirable characteristics shall be mounted on a closed cycle cryogenic refrigerator (capable of providing temperatures near 77 K), thoroughly tested in the laboratory, and, then, at an outdoor test range. In all cases, the performance of the superconductive antenna will be compared to a reference antenna (of the same size) and amplifier combination (using the current conventional, room temperature technologies) and evaluated in a simulated dense noise environment to verify the capability of the superconductive antenna to detect very weak signals in the presence of intense interfering signals, both in band and out of band. A very compact, co-located array of magnetic sensing coils and associated superconductive amplifiers are to be configured and tested to demonstrate and quantify the direction finding capability for extremely small, co-located superconducting antennas. Finally, a plan is to be prepared to determine how this technology could be matured for deployment in a real military operational environment

PHASE III DUAL USE APPLICATIONS: This type of antenna operating in the HF Band could be deployed on a large variety of military land, sea and air platforms to provide improved communication links. In civilian applications, it could be used in mobile communications base stations (to enhance their visual “disappearance” into the environment), and for satellite ground reception stations.

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KEYWORDS: Hf Antenna Systems; Superconductivity; Direction Finding; Superconducting Quantum Interference Devices (SQUID); Superconducting Quantum Interference Filter (SQIF), Environmental Noise Limited Detection; Cryogenic Refrigerator; Superconductive Parametric Amplifier; Josephson Fluxon Anti-Fluxon Transistor (JFAT); Spur Free Dynamic Range, Fabrication.

SB072-032 **TITLE:** Rapid and Accurate Idea Transfer

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Presentation software or system that can be used to rapidly and accurately communicate complex ideas, plans, and high-quality analyses

DESCRIPTION: It is widely recognized that poorly represented information can lead to unfortunate decisions with disastrous consequences. Edward R. Tufte in particular has documented case studies [1] providing evidence that the "cognitive style" of modern software such as PowerPoint™ tends to "reduce the analytic quality of serious presentations of evidence". Yet the conventions that such software supports are in widespread use, potentially serving as a root cause of systemic underperformance in organizations that depend heavily on the rapid and accurate communication of complex concepts. The consequences of poor idea representation and inaccurate idea transfer are serious in the armed forces as well as diplomatic and commercial realms. Therefore, this solicitation invites proposals for a system that will revolutionize the creation and presentations of briefings to more rapidly and accurately transfer ideas, plans, and high-quality analyses from human mind to human mind.

There are many research questions associated with developing the platonic ideal of presentation software such as PowerPoint. Can a user-friendly author's interface simplify the mechanics of briefing construction? What conventions and abstractions should be embodied in software to help authors refine their thinking and maximize the analytic quality of briefings? What makes a briefing effective and easy to understand, and can information design techniques help to balance the tension between analytic quality and ease of audience understanding? In what form and at what rate should ideas be elaborated for maximum understanding and retention by an audience? What real-time interactions should be supported as the briefing progresses: should the briefer control the audience's attention or vice-versa? Should briefings even be "presented", or should they be considered a novel medium with the nature of an interactive visual essay that is simply "used" by the audience? What are the differences between briefing a single person and briefing multiple people who must all absorb and act in concert on a complex idea? New answers to such questions will lead to novel system designs. Modern technology including computation, networking, visualization and animation, and perhaps even augmented cognition all provide untapped realms for briefing software and hardware that have a potential to go "beyond PowerPoint" in surprising and effective ways.

Proposers are expected to describe a research project with the potential for dramatically improving upon state of the art approaches for creating and absorbing complex ideas, plans, and high-quality analyses. The novel insights behind the proposed concept (based on information design, cognitive psychology, etc) must be clear. A basis of confidence in the proposed idea should be clear. A plan for evaluating the efficacy of the proposed solution relative to the state of the art (PowerPoint) must be articulated. The evaluation should balance factors such as time-to-create a briefing with factors such as the audience's ability to accurately absorb and retain the briefing. If possible, the evaluation factors should also assess the extent to which the briefing software improves the analytic quality and intellectual rigor of the briefing author's ideas. Proposers should strive for generality wherever possible, although it is recognized that in early stages of R&D the system may be most usefully explored in a narrow context (military

planning, daily briefings, etc). In addition, proposers should not be overly constrained by the limitations of widely-deployed software and hardware, yet the SBIR project should lead to a practically deployable system within the 3-5 year timeframe.

PHASE I: Phase I must result in a feasibility study of novel concepts in information design that have a potential to be embodied in software and hardware. Proposers should consider the perspectives of authors, briefers, and audiences. Selective prototyping should provide confidence in the most challenging technical aspects of the proposed system. Phase I must also validate the feasibility of a useable software and system through means, such as worked-through use cases, and concepts of operations.

PHASE II: This phase must result in a proof-of-principle prototype implementation and demonstration and must engage potential customers to increase the likelihood of successful transition.

PHASE III DUAL USE APPLICATIONS: Commercially, the system should be useable by any organization that currently depends heavily on tools such as PowerPoint. Military applications include support for briefing cycles in the context of a battle rhythm as well as any planning, decisionmaking, or coordination activities that are currently routine. Potential transition partners range from acquisition organizations to combatant commands.

REFERENCES: 1) Edward R. Tufte, “Beautiful Evidence”, published 2006 by Graphics Press LLC. Of particular interest is the chapter titled “The Cognitive Style of Powerpoint”.

KEYWORDS: Information Design, Presentation Software, Visual Analytics.

SB072-033 **TITLE:** Common Operating Picture for Information Operations

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: System for visualizing information operations and their relationship to kinetic operations

DESCRIPTION: The objectives of this topic are twofold. The first objective is to develop a meaningful symbology and visual depiction of information operations concepts for the broadest definition of information operations (ranging from psychological operations to network operations). The second objective is to use this symbology to develop a digital information operations picture (DICOP) display system that is analogous to, and integrated, with geographic and kinetic common operation pictures.

Great strides have been made in digitizing the battlefield and developing standardized sets of representations for the commander to visualize the battlefield. However, within this domain, certain challenges exist when dealing with different specializations. For example, a red icon means different things to an infantry officer (interpretation: enemy entity; action: destroy) than to a signal officer (interpretation: asset is disabled, action: fix it). The area of information operations is lacking in visualization support. A succinct and information-rich representation of relatively fluid and qualitative concepts is needed to appropriately map out and assess progress during an information operations campaign and to understand how that operation impacts tactical operations and vice versa. Another challenge is that information operations tend to span areas that are not geographically contiguous. Further this representation should be incorporated into the tactical picture to best assess overall impact and progress. For example, it may be important to map out areas of support from local populations vs. areas populated by adversaries, or to visualize social and communication networks that may or may not correspond to geographical features. These types of impacts will require the commander to understand issues and impacts that may be well outside the defined area of responsibility but have significant consequences to the success (or failure) of a mission.

The technical challenges in developing a meaningful operating picture of information operations are substantial. Key factors include translating traditionally subjective and qualitative concepts from human psychology, culture, and sociology to quantitative representations that support the military decision making process and can be incorporated into the digital tactical picture.

PHASE I: Phase I must result in a feasibility study of novel concepts in information design that have a potential to be embodied in software and hardware. Proposers should plan to develop a meaningful symbology of information operations to represent key qualitative concepts. Breakthroughs in terrorism, social networking, and behavioral studies may lead the way to best visually represent information. In parallel, proposers should investigate how to visualize and manipulate information operations data in a fieldable software/hardware system.

PHASE II: This stage must result in a proof-of-principle prototype implementation and demonstration and must engage potential customers to increase the likelihood of successful transition. Proposers should plan to identify transition paths that take into account state-of-the-art systems such as Command Post of the Future.

PHASE III DUAL USE APPLICATIONS: This technology has potential commercial utility in marketing, advertising, and social networking. With respect to computer network operations there may be analogies to disaster recovery management where the interconnected nature of data, power, and transportation networks must be related to physical disasters such as transformer overloads or hurricanes. Network management applications for Internet Service Providers (ISPs) or telecommunication companies are also natural analogues of computer network operations. On the military side, transition to combatant commands would be ideal.

REFERENCES: 1) US Army War College Information Operations Primer (January 2006): <http://www.carlisle.army.mil/usacsl/publications/IO-Primer-AY06.pdf>
2) "Information Operations". Joint publication 3-13 (February 2006): http://www.dtic.mil/doctrine/jel/new_pubs/jp3_13.pdf
3) Marketing material on Command Post of the Future: <http://www.gdc4s.com/documents/cpof-9-12-06.pdf>

KEYWORDS: Information Design, Social Network Analysis, Visual Analytics, Visualization, Computer Network Operations, Psychological Operations

SB072-034 TITLE: Upconverting Films

TECHNOLOGY AREAS: Materials/Processes, Sensors

OBJECTIVE: Identify and develop innovative technology to enable direct conversion of infrared (IR) incident light into a visible band.

DESCRIPTION: Infrared detection approaches have required significant development of highly sensitive arrays. Recent research has demonstrated the capability of semiconductor nanostructures to respond to incident Infrared (IR) light by a bandgap emission in the visible spectrum. This research will explore how to improve photon collection and conversion efficiencies, dynamic range, sensitivity, image formation, and resolution, and would enhance efforts in developing tactical optical systems.

PHASE I: Conduct a feasibility study on using semiconductor nanostructures in a thin film for IR detection. Assess detector sensitivity, selectivity, spatial, temporal and radiometric resolution, visible spectrum transmissivity, and fabrication technology in a thin film appliqué. The form factor should be equivalent to the lenspiece for ballistic protection goggles. Detection structures may be fabricated directly upon the lenspiece, inlaid into an appliqué layer, or otherwise manufactured without substantially degrading the ballistic protection qualities of the goggles. Total additional weight including any required electronics should be less than 50 grams, visible spectrum transmissivity should be greater than 70 percent. This film should be able to convert at least three non-visible spectrum bands into different visible spectral wavelengths.

PHASE II: Develop the materials and methods identified in Phase I and demonstrate a proof-of-concept lenspiece.

PHASE III DUAL USE APPLICATIONS: The technology developed under this SBIR can be used in military and civilian commercial IR sensing and detection for proximity, thermography and fire sensors.

REFERENCES: 1) K. J. Russell, Ian Appelbaum, H. Temkin, C. H. Perry, V. Narayanamurti, M. P. Hanson and A. C. Gossard, "Room-Temperature Electro-Optic Conversion via Internal Photoemission." Applied Physics Letters 82(18), 2960-2962. (2003).
2) L. H. Acioli, A. S. L. Gomes, Cid B. de Araujo, and C. N. Ironside, "Infrared-to-blue Frequency Upconversion in a Pr³⁺-doped Silicate Fiber." Physical Review B54(13) (1996).

KEYWORDS: IR Detection, Nanostructures, Nano Manufacturing.

SB072-035 TITLE: Metamaterials Lens

TECHNOLOGY AREAS: Materials/Processes, Sensors, Electronics

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: Identify and develop innovative technology to enable metamaterials-based lenses that is capable of imaging beyond the diffractive limit in the visible spectrum.

DESCRIPTION: Recent research with negative index of refraction materials has demonstrated the ability of negative index of refraction materials to resolve features beyond the diffraction limit. However, such performance has not been demonstrated for visible spectrum wavelengths, or in the far field. This research would be focused on developing the theory and demonstrating a lens exploiting metamaterial properties to allow far-field resolution of features beyond the diffraction limit.

PHASE I: Conduct a feasibility study on a metamaterials-based lens. Identify materials and fabrication techniques that have the potential to produce a visible wavelength metamaterials based lens with far-field image formation capability.

PHASE II: Develop the materials and methods identified in Phase I and demonstrate a proof-of-concept array element.

PHASE III DUAL USE APPLICATIONS: The technology developed under this SBIR can be used in military and civilian commercial sensor arrays such as medical imaging technology.

REFERENCES: 1) J. B. Pendry, D. Schurig, D. R. Smith, "Controlling Electromagnetic fields." Science 312(23), 1780 (2006).
2) E. Ozbay, "Plasmonics: Merging Photonics and Electronics at Nanoscale Dimensions." Science 311(5758), 189 (2006)
3) S. Durant, Z. Liu, J. M. Steele, X. Zhang, "Theory of the Transmission Properties of an Optical Far-field Superlens for Imaging Beyond the Diffraction Limit." J. Opt. Soc. Am. B 23(11), 2383 (2006)

KEYWORDS: Visible Wavelength Lens, Nano Manufacture, Metamaterials.

SB072-036 TITLE: Optically Reflecting Flexible Membrane

TECHNOLOGY AREAS: Materials/Processes, Sensors, Electronics, Battlespace

OBJECTIVE: Identify and develop innovative technology to enable optically reflecting flexible membranes capable of operation from visible to far Infrared (IR) wavelengths.

DESCRIPTION: There is an increasing need for military optical and imaging systems to be able to perform optical auto-focus and zoom and in some cases foveation on a scene (i.e. there is a need to be able to rapidly zoom into one

and in some cases multiple areas of a scene). Applications include riflescopes, spotter scopes, imaging for missiles, UAV based overhead surveillance, land based surveillance for unattended sensors/motes (remote sensors) and robotics as well as laser pointing and designating. Today this is done by moving bulky lenses mechanically. An alternative is to use fluidic lenses; however the operating range of wavelengths is very limited. Development of a reflective flexible membrane would satisfy the military need to develop an optical zoom and auto-focus capability from visible wavelengths to far IR. This capability promises to have a revolutionary impact on future military optical systems in providing rapid, multiple optical foveation and zoom capability with Wide Field of View (WFOV) with substantially lower weight, volume, and power, and have no moving parts.

Several approaches may be devised to produce a reflective membrane which is capable of > 50% flexure and which spans the visible to IR wavelengths (0.4 to 5 μm) and has an aperture in the 1mm-1cm range. Innovative approaches are sought to be able to achieve coating, embedding or sandwiching of the reflective layer in the flexible membrane. The key issue will be how to avoid the composite reflective membrane from de-lamination, rupturing, or bunching during cycling and thermal excursion in the military temperature range. The optical properties, morphology, and shape of the reflecting surface are also important to maintain low loss as well as not to introduce severe optical aberrations as the surface flexes. Novel ideas to enable scaling from 1mm to 1cm reflecting flexible mirrors without incurring large aberrations are encouraged. The F number of the reflecting lens is expected to be >2.5. Also of interest is how this reflecting membrane could be used in an auto-focus and variable zoom imaging system.

PHASE I: Conduct a feasibility study to identify an approach to develop an optically reflecting flexible membrane from visible to IR with >98% reflectivity. Identify materials and process techniques that have the potential to produce >50% membrane extension without compromising the optical properties and integrity during cycling and military temperature operation. Define and determine how the reflecting membrane could be used in a variable optical zoom system. As part of the final report, plans for Phase II will be proposed.

PHASE II: This phase will complete the detailed design from Phase I. A critical aspect of this phase will be to develop mechanical models of the reflecting mirror lens to guide development. In addition, this phase is expected to develop the materials and methods identified in Phase I and demonstrate a proof-of-concept flexible reflecting mirror which operates from visible to far IR and has a F number >2.5, >50% flexure, and aperture diameter >2mm. Also, this phase will conduct cycling of the membrane as well as temperature cycling to verify integrity of the reflecting film and its optical properties. Military robustness and functionality should be assessed.

PHASE III DUAL USE APPLICATIONS: There are both commercial and military applications for this technology. Commercial applications include: optical systems such as biological and medical imaging, industrial inspection, and earth/science hyper-spectral imaging. Military applications include: riflescopes, spotter scopes, imaging for missiles, UAV based overhead surveillance, land based surveillance for unattended sensors/motes and robotics as well as laser pointing and designating.

REFERENCES: 1) Silver-Polyimide Nanocomposite Membranes: Self-Generated Highly Reflective Flexible Mirrored Surfaces; Mat. Res. Soc. Symp. Proc. Vol. 775, P7.4.1-6
2) Tunable-focus liquid lens controlled using a servo motor, H. Ren, D. Fox, P. A. Anderson, B. Wu, and Shin-Tson Wu; 4 September 2006 / Vol. 14, No. 18 / Optics Express, 8031-8036.

KEYWORDS: Optical Fluidic Lens, Flexible Membrane, Reflecting Zoom, Material Processing.

SB072-037 **TITLE:** Quantum Entangled Radio Communications

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop an approach to increase communications data rates through exploitation of entangled photons

DESCRIPTION: According to Shannon's law, increasing a communications signal bandwidth is a highly energy efficient approach to increasing the data rate. Increased bandwidth is more easily realized at a higher carrier frequency. Further increases are limited by poor propagation through the atmosphere and other transmission media.

The relationship between minimum signal bandwidth and sampling rate is classically expressed as bandwidth is less than or equal to $1 / \Delta t$. The spread in bandwidth may be interpreted as an uncertainty in the energy of a single photon, and the sampling interval may be interpreted as the uncertainty in the timing of that photon. The inverse relationship between these quantities is expressed in the Uncertainty Principle (U.P.): $\Delta E \Delta t$ is greater than or equal to $\hbar/2$. The U.P. applies to a single quantum state, which may entangle multiple photons. With an appropriate detection protocol, ΔE applies to the sum of all N photons in a single entangled state even though the photons may propagate as a group of N low energy photons. These N photons have low-frequency propagation benefits yet achieve the bandwidth (data rate) classically associated with use of photons N times greater in energy.

For application in free-space communications, the quantum state used must be robust to typical propagation characteristics such as dispersion and attenuation. The quantum state selected during Phase I should be robust to a radiation pattern that is non-uniformly spread of 4π steradians and has greater than 10 dB absorption in the transmission medium. The system concept selected during Phase I should be robust to thermal noise from the environment and receiver at 290K.

The scope of this R&D does not include development of any hardware components such as entangled sources or detectors. Communications schemes open for study under this analytical effort are not limited by availability or maturity of hardware. This development is solely intended to improve communications data rate, not security.

PHASE I: Define an N -entangled photon state and a protocol for information encoding/decoding and signal transmission/reception. Analytically show that in the presence of dispersion and attenuation this approach (neglecting hardware efficiencies) offers higher communications data rates than a classical system transmitting equal non-entangled power.

PHASE II: Define a full radio communications system and the components required to realize this system. Calculate the dependence of data rate on N and on the quality of the components.

PHASE III DUAL USE APPLICATIONS: Poor propagation in urban environments is a familiar phenomenon. In commercial applications as well as military, quantum entangled communications will enable the propagation frequency to be selected for maximum signal availability, entirely independent from the desired data rate.

REFERENCES: 1) Caves, Carlton M. "Quantum-Mechanical Noise in an Interferometer", Physical Review D. Vol 23, No 8, 15 April 1981.

2) Jacobson, Joseph et al., "Photonic de Broglie Waves", Physical Review Letters. Vol 74, No 24, 12 June 1995.

3) Shih, Yanhua. "Entangled Photons", IEEE Journal of Selected Topics in Quantum Electronics. Vol 9, No 6, Nov/Dec 2003

4) Valencia, Alejandra et al., "Entangled Two-Photon Wave Packet in a Dispersive Medium", Physical Review Letters. Vol 88, No 18, 6 May 2002.

KEYWORDS: Quantum, Entangled, Radio, Communications.

SB072-038 **TITLE:** Wireless Power Transmission with Electromagnetic Inductive Coupling

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Design, optimize, prototype, and demonstrate a transmitter and receiver for the wireless transfer of power across short to medium distances

DESCRIPTION: Wireless transmission of power by inducing a current at a distance with the non-radiative component of a time-varying magnetic field has several advantages over more traditional approaches relying on directed radiation by lasers or antennas. Such inductive coupling does not require an unobstructed line-of-sight or a precision tracking system between the transmitter and receiver, is less likely to be vulnerable to interference, may offer size and mass savings over directed radiation systems, and may simultaneously supply power to multiple receivers. Indeed inductive energy transmission schemes have become relatively common for household appliances

such as shavers and toothbrushes (see, e.g., reference [1]). The objective of this topic is to explore the applicability of inductive coupling to the transmission of tactically-useful amounts of energy (in the 100 W to 1 kW) across moderate distances (10 cm to 10 m) while maximizing efficiency and minimizing the size and weight of the transmitter and receiver.

PHASE I: Develop a parametric analytical/computational model for efficiency and transmitter/receiver sizing as a function of top-level design parameters, power level, and transmission distance. The model should enable the exploration of a variety of transmitter and receiver geometries, materials, and frequencies to enable trades and optimization of efficiency and size objectives.

PHASE II: Design and construct a transmitter and multiple receivers that are appropriate for integration as a power distribution system for a proximate cluster of small satellites. Specific mission parameters will be defined during Phase I in consultation with the Government.

PHASE III DUAL USE APPLICATIONS: Military and commercial applications include power re-supply for aircraft, power supply to ground robots, power supply to other mobile devices including laptops, sensors, etc.

REFERENCES: 1) K. Lashkari, S. E. Schladober, and E. H. Lechner, "Inductive Power Transfer to an Electric Vehicle," 8th International Electric Vehicle Symposium, Washington, DC, Oct. 1986.
2) A. Esser, H. C. Skudelny, "A New Approach to Power Supplies for Robots," IEEE Transactions on Industry Applications, Vol. 27, No. 5, Sept./Oct. 1991, pp. 872-85.
3) A. Karalis, J. D. Joannopoulos, & M. Soljacic, "Wireless Non-Radiative Energy Transfer," arXiv Abstract #0611063, <http://arxiv.org/abs/physics/0611063>, Nov. 7, 2006.

KEYWORDS: Wireless Power, Induction, Non-Radiative Energy Transfer, Materials.

SB072-039 TITLE: A Sensor for Relative Position and Attitude Determination

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Design, prototype, and demonstrate a sensor or sensor package that enables the determination of relative position and attitude between two spacecraft or other objects without external signals or inertial references.

DESCRIPTION: The knowledge of relative position and orientation of spacecraft is critical to various functions of formation- or cluster-based satellite missions such as station keeping, collision avoidance, state determination by reference to a single inertially-equipped node, data link and sensor pointing, etc. The objective of this topic is to develop a simple, low-cost, self-contained sensor or integrated sensor suite suitable for nano- or micro-satellite use that would enable the measurement of each of the six components of relative attitude and position to within $\pm 1^\circ$ and ± 10 cm, respectively, in each axis. A refresh rate of at least 1 Hz and operating range between 50 cm and 1 km is desirable, though solutions that cover only portions of this range may be acceptable. The sensor may be either active or passive in nature and may require the placement of hardware on both spacecraft. Sensor mass, size, and cost are the principal optimization objectives subject to the above performance objectives. Collateral signature of the sensor and its robustness to interference should be secondary, but nonetheless important considerations in the design.

PHASE I: Develop one or more sensor designs and performance models intended to meet the objectives of this solicitation.

PHASE II: Select a top-performing Phase I design, and develop and fabricate a version thereof suitable for orbital demonstration on a nano- or micro-satellite mission.

PHASE III DUAL USE APPLICATIONS: Dual use applications include power re-supply for aircraft, power supply to ground robots, power supply to other mobile devices including laptops, and sensors.

REFERENCES: 1) Lamoreux, Pearson, Kamerman, Carter, Freedman, Ramrath; "Relative navigation sensor for autonomous rendezvous and docking"; Laser Radar Technology and Applications VIII, Proceedings of the SPIE, Volume 5086, pp. 317-328 (2003)

KEYWORDS: Spacecraft Navigation, Relative Navigation, Attitude Sensor, Position Sensor

SB072-040 TITLE: Unmanned Underwater Riverine Craft (UURC)

TECHNOLOGY AREAS: Ground/Sea Vehicles

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: Identify and develop innovative technology to enable development of an unmanned underwater vehicle that can penetrate and transit underwater in riverine and shallow water coastal environments and carry out surveillance/reconnaissance and deployment tasks in denied, sensitive or contested areas.

DESCRIPTION: There is an operational need to carry out clandestine surveillance tasks in riverine and shallow water environments. For these, a UURC is needed with capabilities to: navigate submerged in rivers, inlets, and harbors as well as in coastal and shallow water areas; provide persistence in these areas and, provide underwater surveillance (against waterborne traffic, underwater obstacles, bottom and buried objects, specific vessels of interest) with onboard and deployable sensors under low visibility conditions. Be capable of autonomous operation and evasion procedures underwater (maneuver, burrowing, use of obscurants, hibernation mode) including bottom conditions such as in mud and sand particulate, weed beds and rock strata. Communicate surveillance and positional data back to the remote operators; and be deployable by air-drop, surface launch and subsurface launch. The UURC potential surveillance payloads include: acoustic sensors, magnetic sensors, NBC sensor, tracking devices, EO/IR Periscope, side-scan sonar. Deployable payloads include surveillance and listening devices, tagging devices and other packages.

Key mobility attributes will include a long endurance underwater powerplant (possibly including regeneration), accurate depth (buoyancy control) and directional control, accurate positional and obstruction sensing and avoidance for operating in low visibility, confined, and trafficked waters, and remote controllability. New methods of sensing including new ambient systems, touch, heat sensitive and acoustic devices will be needed for controlled bottom movement. A capability for bottom locomotion (crawling) is potentially beneficial in many applications and may be complementary to propelled motion for area positioning. The UURC will be required to operate in areas of tidal rise and fall and in current flows. Covertiness of the vehicle and sensors is important for successful use of the system in many expected scenarios and systems for avoidance such as river/sea floor burrowing. It is further desirable for the vehicle to have the ability to regenerate or harvest power for sustained endurance operation or to be able to enter a "sleep" mode for sustained periods pending planned recovery.

Specific technical challenges include: Situational awareness (navigation, route planning, current/tidal effects, obstacle detection), precision vehicle control, very low detectability, efficient power systems (propulsion engine, energy storage, hibernation and energy harvesting), buoyancy control or sea/riverbed locomotion, surveillance sensors and payload deployment, and communication strategies involving data to and from the vehicle.

PHASE I: Identify various UURC enabling and/or critical technologies that support persistent underwater surveillance/reconnaissance missions in riverine and other shallow water operational environments. Define technical concepts and provide analysis to support performance projections and current maturity. Assess their feasibility and investigate how they contribute to the overall operational capability and mission effectiveness of the UURC.

PHASE II: Develop and demonstrate the critical technologies identified in Phase I.

PHASE III DUAL USE APPLICATIONS: The technology developed under this SBIR can be used in military and civilian commercial unmanned underwater vehicles (UUVs). There is a civil need for UUVs that can carry out near-bottom search scans with underwater sensors and bottom-penetrating sensors for object detection and underwater topography.

REFERENCES: 1) Fletcher, B. "UUV Master Plan: A Vision for Navy UUV Development" Space and Naval Warfare Systems Center. <http://www.spawar.navy.mil/robots/pubs/oceans2000b.pdf>
2) Johnson, E. UNMANNED UNDERSEA VEHICLES AND GUIDED MISSILE SUBMARINES: Technological and Operational Synergies Occasional Paper No. 27 Center for Strategy and Technology Air War College Air University Maxwell Air Force Base, Alabama. February, 2002
<http://www.au.af.mil/au/awc/awcgate/cst/csat27.pdf>

KEYWORDS: Underwater, Riverrine, Shallow-water, Persistence, Covert, Surveillance, Submerged, Obstacle Avoidance and Visually Obscured Submerged Environments.

SB072-041 TITLE: Energy Storage Systems for Very High Altitude Very Long Endurance Solar Aircraft

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Identify and develop innovative technologies for very high specific energy storage systems suitable for a very high altitude, very long endurance solar electric aircraft.

DESCRIPTION: DARPA is interested in the technologies necessary for building HALE (high altitude, long endurance) aircraft with multi-year endurance. For a solar-electric-powered "stepping-stone" version of this aircraft with multi-month endurance, one key technology need is the ability to reversibly store and release electrical energy on a diurnal basis with an extremely low weight system. The stringent weight requirements dictate that the specific energy of the total storage system exceeds 1350 W-hr/kg, with a goal of 2000 W-hr/kg desired, and with the ability to completely charge the system during a 9 hour "daylight" period, and release nearly all of the energy at a rate of 1 kW during a 15 hour "night" period. Additionally, since the system can not have any maintenance over a period of >2000 hrs, the system, by design, must stress very high inherent reliability. Furthermore, the system design should accommodate the realities of the environment (i.e. temperatures of approximately -70C and pressures ~3% of sea level) which can be expected at ~100kft, while understanding that the aircraft will occasionally need to traverse from sea level to altitude and back again during launch and recovery.

Solid oxide fuel cells (SOFCs) appear to be a potentially attractive candidate for this type of an energy storage system. Recent work by the NASA Glenn Research Center (1) has demonstrated a series of novel fabrication approaches that appear to make the goals of this topic potentially attainable, perhaps if the fuel cell can be "air breathing". Other technologies, such as polymer electrolyte membrane (PEM) fuel cells (2), and novel battery technologies, such as Lithium-Air (3), may be suitable if their performance can be improved and they are able to operate in this extreme environment. Other alternative technologies will definitely be considered. Both new technical solutions for overcoming specific technical hurdles and examination of the system requirements/design for a regenerative cycle are of interest.

PHASE I: Conduct a feasibility study on very high specific energy systems capable of meeting the electrical, reliability, and environmental requirements suitable for use on a extreme solar HALE aircraft with multi-month endurance operating at ~100kft. Include a comparison of a closed-loop "pure oxygen system" vs. an "air breathing" regenerative system. Identify key materials and sub-systems requiring development and present a credible plan to accomplish these tasks. Possibly demonstrate some key sub-system performance.

PHASE II: Develop the materials and sub-systems identified in Phase I and demonstrate a proof-of-concept laboratory system capable of unattended operation >250 hours in a simulated very high altitude (~100kft) pressure and temperature environment.

PHASE III DUAL USE APPLICATIONS: The technology developed under this SBIR can be used in military and civilian commercial applications such as domestic heating and cooling and future distributed energy systems.

REFERENCES: 1) Cable, T., Salamone, S., Setlock, J. Farmer, S. "Proof of Concept (Design, Fabrication, and Testing) of a Novel High Power Density Solid Oxide Fuel Cell Established." Aeronautics Research, VSP. <http://www.grc.nasa.gov/WWW/RT/2005/RX/RX38C-cable.html>
2) Mitlitsky, F. "The Unitized Regenerative Fuel Cell" Science and Technology Review, May 1997. <http://www.llnl.gov/str/Mitlit.html>
3) Georgi, D. "Lithium Primary Continues to Evolve." 42nd Power Sources Conference, http://www.batteriesdigest.com/lithium_air.htm

KEYWORDS: Solid Oxide Fuel Cells, Regenerative Fuel Cells, PEM, Batteries.

SB072-042 TITLE: Low-Stored-Volume Wings for a Very High Altitude Aircraft

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Identify and develop innovative, very lightweight, low-stored-volume very high lift to drive (L/D) wing technologies for a very high altitude, long endurance aircraft (HALE).

DESCRIPTION: DARPA envisions developing the technologies capable of deploying a long endurance aircraft from a low-stowed-volume configuration that has been delivered to a high altitude. One key technology required for this capability is a low-stored-volume, very high L/D wing with significant wing area. For the requirements of the intended HALE aircraft, conventional wing technology would constitute the vast majority of the stored volume, so suitable alternatives are required. The problem is compounded by both the structural and airfoil shape demands that are required for a very high L/D, very high altitude aircraft associated with low density, low Reynolds number flow.

There are a few potential technologies that might be considered. NASA has examined inflatable wings for small, utility aircraft and found that they could work for applications where volume constraints precluded other alternatives. Other alternative technologies will definitely be considered.

PHASE I: Conduct a feasibility study for low-stored-volume, very high L/D (at least 30) wing technologies capable of meeting the stability, reliability, and environmental requirements suitable for use on an extreme HALE aircraft with a 24 hour endurance. Identify key materials and sub-systems requiring development and present a credible plan to accomplish these tasks. Perform initial experimentation demonstrating the concept.

PHASE II: Develop the materials and sub-systems identified in Phase I and demonstrate a proof-of-concept system, conduct experiments to demonstrate performance and test its deployment at >90 kft.

PHASE III DUAL USE APPLICATIONS: The technology developed under this SBIR can be used in military and civilian commercial applications such as improved air transportation systems.

REFERENCES: 1) Edwards. "Inflatable Wings Given a Flutter." Space Daily. July 9, 2001. <http://www.spacer.com/news/plane-inflatable-wing-01a.html>

KEYWORDS: Very High Altitude, Aircraft, Wings.

SB072-043 TITLE: Photovoltaic Cells for Very High Altitude Very Long Endurance Solar Aircraft

TECHNOLOGY AREAS: Air Platform, Space Platforms

OBJECTIVE: Identify and develop improved technologies for inexpensive, very high efficiency, thin film photovoltaic cells suitable for a very high altitude, very long endurance solar aircraft.

DESCRIPTION: DARPA is interested in the technologies necessary for building HALE (high altitude, long endurance) aircraft with multi-year endurance. For a solar-electric-powered version of this aircraft with multi-year

endurance, one key technology need is the ability to collect energy from the sun and environment in a highly efficient manner in a system with minimal mass. The requirements for these planer cells are a minimum of 35% conversion efficiency (40% is the goal) at 100 kft air density environment (Air Mass 0) at Room Temperature on an insulated substrate with 60 knots air flow with full solar illumination over a full angular range of 60 degrees off normal, with an array mass density of <325 g/m² (275 g/m² goal), including interconnections and diodes, with a panel design life goal >40,000 hours. Furthermore, some degree of flexibility will be required, equivalent to wrapping the cells around a 30cm diameter cylinder. Finally, the basic technological approach proposed should have a credible pathway to providing these cells at relatively low cost.

Thin-film photovoltaic cells, gallium arsenide (GaAs) cells on various substrates, many types of tandem structures, and nanocrystal (quantum dot) solar cells all hold the promise of meeting these requirements, but any technology that can fulfill the above requirements is desired.

PHASE I: Conduct a feasibility study on very high efficiency photovoltaic cells capable of meeting the electrical, physical, design life, and environmental requirements suitable for use on a solar HALE aircraft with multi-month endurance at relatively low cost. Identify key materials and sub-systems requiring development and present a credible plan to accomplish these tasks.

PHASE II: Develop the materials and sub-systems identified in Phase I and demonstrate a proof-of-concept laboratory system of at least 0.5m² capable of meeting all of the requirements (except design life goal) in a simulated 100 kft temperature and pressure environment at simulated 60 knot speed condition.

PHASE III DUAL USE APPLICATIONS: The technology developed under this SBIR can be used in military and civilian commercial applications such as domestic heating and cooling and distributed energy systems.

REFERENCES:1) "Sunny Future for Nanocrystal Solar Cells." Lawrence Berkley National Laboratory. ScienceDaily, October 23, 2005 <http://www.sciencedaily.com/releases/2005/10/051023122429.htm>
2) Weiss. P. "Quantum Dot Leap." Science News Online. Vol 169. No. 22. P. 344. June 3, 2006. <http://www.sciencenews.org/articles/20060603/bob8.asp>

KEYWORDS: Photovoltaic Cells, Solar Cells, Nanocrystal Cells.

SB072-044 TITLE: Reduction of Structural Mass Fraction for Extreme Solar HALE Flying Wings

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Identify and develop improved technologies for reducing the structural mass fraction of extreme solar HALE (high altitude, long endurance) aircraft.

DESCRIPTION: DARPA is interested in the technologies necessary for building HALE (high altitude, long endurance) aircraft with multi-year endurance. For a solar-powered extreme HALE "stepping-stone" version of this aircraft with multi-month endurance, one key technology need is the ability to reduce the structural mass fraction while maintaining the performance and reliability. At these extreme altitudes (90-100 kft), the potential wing loading will be 0.6-0.7 lbs/sqft and weight budgets for all aspects of the craft will be particularly challenging. Unfortunately for the structural design, it is difficult to evaluate the potential maximum loads given the stochastic nature of the wind and gust environment, during both the launch and recovery phases, as well as during the time on station. These loads lead to the most troubling instability, i.e. buckling. Designing to the 99.99% load in the traditional manner is not an option because the structural mass fraction would become much too large. Therefore, new design approaches will be needed.

A number of potential approaches can be envisioned. These include independent, distributed control along the length of the wing to counteract the natural response of a flexible wing structure to pre-load the center section (as was seen with NASA's Helios). Another approach might be to use a different type of thick-chord wing design that minimizes the impact of local non-linear behaviors, such as skin wrinkling. Other alternative technologies will definitely be considered.

PHASE I: Conduct a feasibility study on one or more methods to reduce the structural mass fraction of extreme solar HALE flying wings. Identify key sub-systems requiring development and present a credible plan to accomplish these tasks.

PHASE II: Develop the sub-systems identified in Phase I and demonstrate a proof-of-concept laboratory system that validates the new design methodology on an extremely lightweight, thick chord wing structure.

PHASE III DUAL USE APPLICATIONS: The technology developed under this SBIR can be used in both military and civilian commercial applications such as improved air transportation systems.

REFERENCES: 1) Patil, M. and Hodges, D. "Flight Dynamics of Highly-Flexible Flying Wings." International Forum on Aeroelasticity and Structural Dynamics" June 28-July 1, 2005.

http://www.aoe.vt.edu/~mpatil/presentations/HALE_files/frame.htm

2) Lienhard, J. "Flying to the Edge of Air." The Engines of Our Ingenuity. Episode 1639. <http://www.uh.edu/engines/epi1639.htm>

KEYWORDS: Distributed Controls, Efficient Structural Design.

SB072-045 TITLE: Very High Altitude Aircraft Propulsion Engines

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Identify and develop innovative aircraft propulsion engine technologies for a very high altitude, long endurance aircraft.

DESCRIPTION: DARPA is interested in developing the technologies necessary for deploying a very high altitude aircraft having 12-20 hour endurance. One key technology required for this capability is an engine capable of sustained operations at very high altitudes (~90kft) which can be stored in a sealed container for months at a time and yet deliver the thermal efficiency (~40%) required for long endurance flight. The stringent weight and volume requirements for this type of aircraft preclude using traditional multistage compressor technologies and suggest that alternative approaches (perhaps mono-propellants) may provide suitable alternatives.

During 1975 through 1977, NASA did some preliminary investigations of a very high altitude (>80kft) air-sampling aircraft under the Mini-Sniffer Program. The last vehicle in this program, Mini-Sniffer III, used a mono-propellant hydrazine-powered engine that was designed to operate for extended periods over 80 kft. Though a number of operational problems prevented demonstration of the high-altitude capability of Mini-Sniffer III, updated versions of this basic engine approach, possibly using a less hazardous propellant, may hold promise for DARPA applications. Other alternative technologies will definitely be considered.

PHASE I: Conduct a feasibility study for a very high altitude (~90 kft) aircraft propulsion engine capable of meeting the stability, reliability, and environmental requirements suitable for use on an extreme HALE aircraft with 12-20 hour endurance that must be stored for months. Projected power requirements would be ~40 HP. Identify key materials and sub-systems requiring development and present a credible plan to accomplish these tasks.

PHASE II: Develop the materials and sub-systems identified in Phase I and demonstrate an ~40 HP proof-of-concept laboratory system capable of both starting and continuous operation >12 hours in simulated very high altitude (~90kft) pressure and temperature environment.

PHASE III DUAL USE APPLICATIONS: The technology developed under this SBIR can be used in military and civilian commercial applications such as emergency power and atmospheric research.

REFERENCES: 1) Mini-Sniffer III on Lakebed with Ground Support Crew. Photograph Number ECN-6134. November 30, 1976

<http://www1.dfrc.nasa.gov/Gallery/Photo/Mini-Sniffer/HTML/ECN-6134.html>

KEYWORDS: Very High Altitude, Engine, Propulsion.